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APPENDIX B

Performance Monitoring Plan

APPENDIX B

PERFORMANCE MONITORING PLAN
ST. LOUIS TUNNEL DISCHARGE
CONSTRUCTED WETLAND DEMONSTRATION
TREATABILITY STUDY WORK PLAN
Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Dolores County, Colorado

October 2013

Project SA11161315

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ATTACHMENTS

LIST OF ABBREVIATIONS

AMEC	AMEC Environment & Infrastructure, Inc.
Atlantic Richfield	Atlantic Richfield Company
BOD	biological oxygen demand
Cd	cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DO	dissolved oxygen
FDB	flow diversion box
Fe	iron
FM01	influent flowmeter for SB No. 1
FM02	influent flowmeter for SB No. 2
FM03	influent flowmeter for the standalone surface flow wetland
FM04	effluent flowmeter for the rock drain
$g/m^2/d$	gram per square meter per day
gpm	gallon per minute
H_2S	hydrogen sulfide
HRT	hydraulic residence time
HSSE	Health, Safety, Security and Environment
IDLH	Immediately Dangerous to Life and Health
LiCl	lithium chloride
location ID	location identification
mg/L	milligrams per liter
Mn	manganese
MnO_2	manganese dioxide
MOS	metal oxide semiconductor
mV	millivolt
NaBr	sodium bromide
NELAP	National Environmental Laboratory Accreditation Program
No.	number
ORP	oxidation reduction potential
Pace	Pace Analytical Laboratories, Inc., Lenexa, Kansas
PMP	Performance Monitoring Plan
ppm	parts per million
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
QC	quality control
RAWP	Removal Action Work Plan
RTD	residence time distribution
SB No. 1	Settling Basin Number 1
SB No. 2	Settling Basin Number 2
SEC	specific electrical conductance
SF	surface flow
site	Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01, Dolores County, Colorado
SOP	Standard Operating Procedure
SRB	sulfate-reducing bacteria
SSF	subsurface flow

LIST OF ABBREVIATIONS (CONTINUED)

TOC	total organic carbon
TSEAs	Task Safety Environmental Analyses
TSHASP	Task Specific Health and Safety Plan
TSS	total suspended solids
U.S. EPA	United States Environmental Protection Agency
UAO	Unilateral Administrative Order
wetland demonstration	constructed wetland demonstration treatability study
Work Plan	St. Louis Tunnel Discharge Constructed Wetland Demonstration Treatability Study Work Plan, Revision 1
Zn	zinc

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PERFORMANCE MONITORING PLAN
ST. LOUIS TUNNEL DISCHARGE CONSTRUCTED WETLAND DEMONSTRATION TREATABILITY STUDY WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Dolores County, Colorado

1.0 INTRODUCTION

This *St. Louis Tunnel Discharge Constructed Wetland Demonstration Performance Monitoring Plan* (PMP) has been prepared by AMEC Environment & Infrastructure, Inc. (AMEC), on behalf of Atlantic Richfield Company (Atlantic Richfield), to describe the sampling, analysis, and monitoring that will be conducted during the constructed wetland demonstration treatability study (wetland demonstration) at the Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01, Dolores County, Colorado (site). The discharge from the St. Louis Tunnel has a circumneutral pH, but has elevated concentrations of dissolved zinc (Zn), cadmium (Cd), and manganese (Mn), as well as particulate iron (Fe). The passive, constructed wetland system will be evaluated as a potential method for mitigating metals discharging to the Dolores River.

The activities described in this PMP and the *St. Louis Tunnel Discharge Constructed Wetland Demonstration Treatability Study Work Plan Revision 1* (Work Plan; Atlantic Richfield, 2013a) are being conducted pursuant to the Unilateral Administrative Order for Removal Action (UAO), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No. 08-20011-0005, effective March 23, 2011 (UAO; U.S. Environmental Protection Agency [U.S. EPA], 2011a), and the associated Removal Action Work Plan (RAWP) dated March 9, 2011 (U.S. EPA, 2011b). This PMP has been developed pursuant to Task F Subtask F2 of the RAWP, which requires the completion of treatment system conceptual designs and additional investigations to compare alternatives and support water treatment system designs.

The wetland demonstration is being implemented to further evaluate passive constructed wetlands as a method for treating mine water that discharges from the St. Louis Tunnel. Recommendations developed from a previous pilot-scale constructed wetland will also be implemented. Results of the pilot-scale wetland test are described in further detail in the *St. Louis Tunnel Discharge Constructed Wetland Pilot-Scale Test Completion Report* (AMEC, 2013a). The wetland demonstration will provide treatment performance data to support a comparative evaluation of this treatment approach to other treatment methods. If a passive constructed wetland system is selected for full-scale treatment of the St. Louis Tunnel discharge, information from the wetland demonstration will provide design parameters as well as information about operations and maintenance that will be needed for scale-up. The sampling, analysis, monitoring, and testing activities that are described in this PMP will be implemented to gather this information during operation of the constructed wetland demonstration.

1.1 HEALTH, SAFETY, SECURITY, AND ENVIRONMENT EXPECTATIONS

All tasks described herein will be performed in accordance with the Task Specific Health and Safety Plans (TSHASPs) prepared by Atlantic Richfield's contractors. The appropriate Risk Assessments, Task Safety Environmental Analyses (TSEAs), Standard Operating Procedures (SOPs), and permits will be completed prior to initiating any of the work described herein in accordance with site Health, Safety, Security, and Environment (HSSE) requirements.

All on-site sampling, monitoring, and testing activities that will be conducted during winter conditions will be governed by a Winter Access and Operations Plan, which will outline winter access safety requirements and guide safe decision making with respect to weather and avalanche conditions. Procedures that will be followed during winter 2013/14 will be similar to procedures that were followed during the pilot-scale wetland winter testing period, when the timing of monitoring and sampling events were adjusted based on site access conditions. The Winter Access and Operations Plan for 2013/14 will be finalized and approved prior to conducting winter operations for the wetland demonstration.

Specific HSSE considerations for operation, maintenance, and monitoring of the wetland demonstration have been mitigated through system design. Additional hazards associated with the sampling and monitoring activities during all phases of the wetland demonstration will be mitigated through Control of Work risk assessments and the Hazard Identification process.

1.2 COORDINATION AND RESPONSIBILITIES

The project team for startup, operation, maintenance, and monitoring of the wetland demonstration will consist of key personnel from Atlantic Richfield and their contractors. The sampling and monitoring tasks for the wetland demonstration will be conducted by Atlantic Richfield and their contractor personnel.

Detailed roles and responsibilities will be reviewed with the entire project team prior to the start of work. The project team also will be periodically informed of wetland demonstration progress, as described in Section 8.

1.3 DOCUMENT ORGANIZATION

This PMP describes the activities that will be completed to fulfill the objectives of the wetland demonstration. This PMP includes field sampling plans for each unit operation, descriptions of sampling and monitoring methods, an estimated implementation schedule, and a description of reporting. Following this introduction, this PMP is organized into the following sections:

- Section 2 describes the objectives for the wetland demonstration and for the PMP.
- Section 3 presents a general overview of the planned operations during each phase of the wetland demonstration.
- Section 4 presents field sampling plans for each unit process, providing guidance for the field work that will be used to complete the tasks and satisfy the specific unit process objectives.
- Section 5 describes hydrogen sulfide gas (H_2S) monitoring that will be conducted.
- Section 6 briefly describes the tracer tests that will be conducted.
- Section 7 describes the quality assurance and quality control (QA/QC) protocols needed to achieve the decision objectives.
- Section 8 presents the estimated implementation schedule for the wetland demonstration.
- Section 9 outlines the reporting planned in support of the wetland demonstration.
- Section 10 lists references used in preparing this PMP.

2.0 OVERVIEW AND OBJECTIVES

2.1 WETLAND DEMONSTRATION OVERVIEW AND OBJECTIVES

The design of the wetland demonstration system is based largely on the findings of the pilot-scale wetland test. The system is designed to treat 30 gallons per minute (gpm), but will be able to treat flows ranging from 10 to 50 gpm. Influent to the system will be a slipstream of water from the St. Louis Tunnel discharge channel, piped from the existing flow diversion point immediately downstream of the DR-3 surface water sampling location and the Parshall flume (Figure B-1). The demonstration system consists of the following unit processes in series:

- A settling basin (SB No. 1; Figure B-2) with a flocculant injection system, designed to remove suspended solids, primarily composed of particulate iron (Fe), by coagulation and sedimentation;

- A polishing surface flow (SF) wetland (Figure B-3) designed to provide additional removal of suspended solids;
- An anaerobic subsurface flow (SSF) wetland (Figure B-4) to promote biological sulfide production for precipitation of Cd and Zn sulfides;
- An aeration channel (Figure B-5) designed to promote elemental sulfur precipitation, decrease H_2S gas production, settle precipitated sulfur and sloughed biomass, remove biochemical oxygen demand (BOD), and increase dissolved oxygen (DO) concentrations in the SSF wetland effluent; and
- An aerobic rock drain (Figure B-5) designed to oxidize dissolved Mn and precipitate insoluble manganese dioxide (MnO_2).

Effluent from the rock drain will flow into the northern end of Pond 18 (Figure B-1).

In addition to the main wetland demonstration process flow train, two standalone treatment units (Settling Basin Number 2 [SB No. 2] and the standalone SF wetland, shown in Figures B-2 and B-6, respectively) will be constructed to evaluate different suspended solids removal technologies, independently of the main wetland demonstration. Effluent from both of these unit processes will be discharged into Pond 18.

Further details of the wetland demonstration system background, objectives, and design parameters for each unit process of the wetland demonstration are presented in the Work Plan (Atlantic Richfield, 2013a). Information from the wetland demonstration will provide design parameters as well as information about operations and maintenance that will be needed for scale-up, if constructed wetland technology is selected as part of the final remedy for treating the St. Louis Tunnel discharge. As stated in the Work Plan (Atlantic Richfield, 2013a), the primary objectives of the wetland demonstration are to:

- Determine the attainable treatment performance of a passive treatment system, without the addition of an external heat source (i.e., heat trace), for reducing the concentrations of Cd, Fe, Mn, total suspended solids (TSS), and Zn in water taken directly from the St. Louis Tunnel discharge.
- Relate observed matrix material decomposition, accumulation and management of treatment byproducts, and construction material integrity (e.g., geomembranes, flow control structures) to anticipated performance lifetime for a passive treatment system.
- Evaluate H_2S production and potential HSSE, operational, or engineering control mitigation methods, such as a reduction of matrix material organic components, nutrients, or sulfur prill content, for full-scale operation.

- Establish the land surface requirements for full-scale implementation of a constructed wetland passive treatment system.

- To the extent possible during the demonstration wetland test, identify seasonal and long-term treatment performance variations and potential proactive maintenance or engineering controls.

The specific objectives for each unit process as presented in the Work Plan (Atlantic Richfield, 2013a) are also presented in Section 4 of this PMP, along with the sampling, analysis, monitoring, and testing that will be conducted to meet the specific objectives for each unit process.

2.2 PERFORMANCE MONITORING PLAN OBJECTIVES

The sampling, analysis, monitoring, and testing activities as described in this PMP will ensure that the sampling and data collection activities will meet the overall objectives of the wetland demonstration and the specific objectives for each unit process that are presented in the Work Plan (Atlantic Richfield, 2013a).

The objectives of this PMP are therefore to:

- Provide guidance for field, laboratory, data collection, and sample analysis activities so that the results will meet the objectives and tasks of the wetland demonstration.

- Ensure that sampling and data collection activities will be comparable to and compatible with previous data collection activities.

- Provide a mechanism for planning and approving field activities.

The field sampling plans for each unit process (Section 4) describe the sampling activities, analytical procedures, and sampling schedules that will be used for evaluating treatment performance under different operating conditions. The results of the activities described in this PMP are intended to support future activities at the site, including treatment technology evaluation, alternatives evaluation, technology selection, and future treatment system design. The completed wetland demonstration is expected to provide valuable information on the design parameters for effective passive treatment of site contaminants.

3.0 GENERAL OVERVIEW OF PLANNED OPERATIONS

This section presents a general overview of the wetland demonstration, summarizing the normal operations, operational changes, and sampling and monitoring that will be conducted during the major phases of the wetland demonstration.

This PMP describes monitoring that will be completed after the wetland demonstration system has been constructed. Additional sampling and analysis of matrix materials is planned for the construction phase, as describe in the Work Plan (Atlantic Richfield, 2013a).

3.1 BASELINE

The baseline phase is assumed to start after construction activities have been completed and will be conducted before introducing flow into the system. The purpose of the baseline activities is to determine as-built conditions and to establish initial operational conditions of the wetland demonstration. Baseline results will be compared to results of surveys that will be completed after testing to determine as-built conditions and changes over the course of the treatability study.

Baseline activities will include an as-built survey of the entire wetland demonstration system. A licensed surveyor will be subcontracted to survey horizontal and vertical coordinates of the each unit process, inlet and outlet flow control structures, the tops of the monitoring ports, monitoring locations, and the top of the matrix near the SSF wetland monitoring ports. The standalone SF wetland, polishing SF wetland, SSF wetland, aeration channel, and rock drain will be surveyed both after liner placement and after the placement of the matrix material to calculate the depth and volume of media installed. Surveying will also be conducted in the settling basins and SF wetland for later estimation of solids deposition.

After the placement of the SSF wetland matrix material and following the wetland demonstration testing, the wetland monitoring ports and the matrix surface near the monitoring ports will be surveyed. Initial baseline elevations will be compared to elevations from subsequent periodic surveys to assess the degree of consolidation that occurs during the demonstration, and results may provide information to determine the rate of matrix consolidation. Generally, two surveys per year will be completed for comparison, starting with Fall 2013 and Spring 2014 and continuing with late fall and late spring surveys if monitoring of the wetland demonstration continues.

Selected matrix materials will be sampled and analyzed to quantify baseline metals concentrations in the inoculated SSF wetland and rock drain. SSF wetland material will also be sampled and analyzed to establish the baseline physical properties (porosity and permeability) of matrix material after placement. Total depths of all SSF wetland and rock drain monitoring ports will be measured to assess sediment accumulation as the wetland demonstration progresses. Flow of mine water will be introduced to the system at the end of the baseline phase.

3.2 COLONIZATION

Microbial cultures will be introduced to two of the unit processes to initiate growth and establish populations for reducing the concentrations of target metals. Sulfate-reducing bacteria (SRB) will be introduced to the SSF wetland, and manganese-oxidizing bacteria will be introduced to the rock drain. Microbial cultures from the pilot-scale system will be used for inoculation of the SSF wetland (Section 4.3.3 of the Work Plan) and the rock drain (Section 4.5.3 of the Work Plan). During the colonization period, the influent flow rate to the system will be adjusted to approximately 30 gpm, which will allow microorganisms to grow and adapt to the design flow rate of the system, which should prevent sloughing of biomass when the wetland demonstration starts.

During the colonization period, operational parameters of each unit process will be noted, flow rates will be noted, water samples will be collected, and water quality parameters will be measured. Additional details of sampling and monitoring that will be conducted for each unit process during the colonization phase are provided in Section 4 of this PMP.

During the colonization phase, continuous measurements of water quality parameters will be recorded to document the influent and effluent water chemistry through each unit process. Parameters that will be measured will include pH, specific electrical conductance (SEC), temperature, oxidation reduction potential (ORP), and DO. Water quality parameters will be measured by data logging sondes programmed to measure water quality parameters once every six hours. Data will be downloaded from each sonde approximately once per week to assess changes in process chemistry and sensor drift. Discrete water quality measurements will also be measured approximately weekly using calibrated instrumentation. Grab water quality parameters will be compared recorded values measured by the deployed sondes to determine sonde sensors need to be recalibrated. The schedule for making water quality measurements and downloading data may be adjusted based on weather conditions and safe access to the site, as discussed in Section 1.1.

Colonization of the SSF wetland will be considered to be complete and the wetland demonstration testing will commence when the ORP at the SSF wetland outlet (SSFWMP11; Figure B-4) decreases to less than -100 millivolts (mV). It is anticipated that the colonization period may take up to one month; however, use of the pilot-scale wetland matrices for inoculum should decrease this duration. Based on results of the pilot-scale wetland, readily measurable water quality criteria cannot be used to assess colonization of the rock drain. Colonization of the rock drain will be assessed using visual observations of MnO_2 accumulation, and post-colonization evaluation of Mn data will be used for confirmation.

Temperatures during colonization will be measured throughout the system to assess heat loss. Four types of devices with data-logging capabilities will be used to measure and record temperatures:

1. Temperature probes for measuring and recording influent and effluent temperatures;
2. Vertical temperature probes for measuring and recording vertical profiles of matrix temperatures;
3. Data logging sondes; and
4. Pressure transducers with temperature loggers.

Further details of sampling, analysis, monitoring, and testing to be conducted during the colonization phase are described in Section 4 for each unit process.

3.3 WETLAND DEMONSTRATION TESTING

Once the SSF wetland and the rock drain have been colonized, the first wetland demonstration test run will commence. The initial influent flow rate will be set to the design flow rate of 30 gpm.

During the wetland demonstration testing operational parameters of each unit process will be recorded, flow rates will be measured, water samples will be collected, and water quality parameters will be measured. Tracer testing will be conducted on select unit processes to determine hydraulic characteristics, and hydraulic testing (i.e., slug testing) will be conducted in the SSF wetland to estimate hydraulic conductivity. Section 4 provides additional details of the locations and methods that will be used for sampling, monitoring, and testing of each unit process during the wetland demonstration.

During the wetland demonstration phase, continuous measurements of water quality parameters will be recorded to document the influent and effluent water chemistry through each unit process. Parameters that will be measured will include pH, SEC, temperature, ORP, and DO. Water quality parameters will be measured by data logging sondes programmed to measure water quality parameters once every six hours. Data will be downloaded from each sonde approximately twice per month to assess changes in process chemistry and sensor drift. Discrete water quality measurements will also be measured approximately twice per month using calibrated instrumentation. Grab water quality parameters will be compared recorded values measured by the deployed sondes to determine sonde sensors need to be recalibrated. The schedule for making water quality measurements and downloading data may be adjusted based on weather conditions and safe access to the site, as discussed in Section 1.1.

Temperatures during the wetland demonstration will be continuously measured throughout the system to assess heat loss, using the four types of devices as listed in Section 3.2.

Demonstration testing will continue throughout the winter of 2013/14 and into 2014. Access during winter conditions for monitoring, sampling, and testing activities will be dependent on weather conditions and will be assessed per the Winter Access and Operations Plan (to be developed). It is anticipated that the flow rate through the system will be changed after approximately six weeks of operation at 30 gpm flow rate. The flow rate will be adjusted (increased or decreased) to test the treatment performance and the hydraulic response of the system for a range of nominal hydraulic retention times (HRT).

3.4 POST-WETLAND DEMONSTRATION

Post-wetland demonstration activities will be completed to evaluate the final operational conditions of the wetland demonstration and to determine changes in the system as compared to baseline conditions. Water samples will be collected, water quality parameters will be measured, and logged data will be downloaded.

Post-demonstration sampling and measurements will be completed to determine physical changes caused by operation of the system. Water levels and total depth of monitoring ports will be measured to evaluate changes in flow characteristics and to measure the accumulation of sediment. Matrix samples will be taken from the subsurface flow (SSF) wetland to determine changes in flow characteristics (i.e., porosity and permeability), which may be cause by settling or decomposition of the SSF wetland matrix material or due to plugging and/or fouling by precipitates and biomass during system operation. Matrix, sediment, and sludge samples will be taken from throughout the system to characterize the solids that accumulate during operation of the system. Specifically, matrix materials from the SSF wetland and rock drain will be sampled and chemically characterized to quantify metal accumulation over the course of the study.

Additional details of post-wetland demonstration sampling, analysis, and testing for each unit process are provided in Section 4.

4.0 FIELD SAMPLING PLANS FOR INDIVIDUAL UNIT PROCESSES

The following sections describe the field sampling, monitoring, and testing that will be conducted to meet the treatability study objectives for each unit process. Additionally, operation and maintenance of each unit process is briefly described. The general layout of the entire wetland demonstration system is shown on Figure B-1 and Figures B-2 through B-5 present details of sampling locations for the unit processes. Two tables are presented for each unit process: one listing data that will be collected to evaluate and satisfy the specific treatability study objectives and one that summarizes the field sampling plan. All sampling, monitoring, and testing will be conducted in accordance with the appropriate Standard Operating Procedures (SOPs) as provided in Attachment B-1.

4.1 SETTLING BASIN NUMBER 1

SB No. 1 is the most upstream component of the wetland demonstration treatment train (Figure B-1). SB No. 1 will receive untreated influent from the St. Louis Tunnel discharge. The primary treatment objective for SB No. 1 is to utilize gravitational settling to remove suspended solids and particulate Fe upstream of the SSF wetland and rock drain. SB No. 1 includes a flocculant injection system to enhance particle formation and increase settling velocities, which should improve particulate removal. Removal of particulate Fe and TSS in SB No. 1 is intended to minimize interferences with metals removal processes in the SSF wetland and the rock drain and will reduce the potential for particulates to clog the wetland matrix material.

The specific treatability study objectives for SB No. 1 and the methods by which these objectives will be evaluated during wetland demonstration are presented in Table B-1. To achieve these objectives, the field sampling plan that is summarized in Table B-2 will be followed. The sampling and monitoring locations for SB No. 1, including locations for post-treatability study sludge sampling, are shown on Figure B-2. The following subsections summarize the operations and field activities that will be completed for SB No. 1.

4.1.1 Baseline

A post-construction survey will be performed to determine as-built conditions of SB No. 1.

4.1.2 Colonization Phase

Colonization of SB No. 1 is not necessary because this is not a biological process. However, during the colonization period for the entire system, the flow rate through SB No. 1 will be set to the design flow rate of 30 gpm, which will result in a nominal hydraulic residence time (HRT) of about 17.6 hours. Treatment effectiveness in SB No. 1 will be dependent on correct chemical dosing to enhance removal of TSS and particulate Fe. Thus, the colonization period will be used to observe the effects of the initial chemical dosage.

Initial laboratory jar testing has been completed with mine water from the St. Louis Tunnel discharge (AMEC, 2013b). The objective of the testing was to evaluate the ability of different flocculants and coagulants to improve removal of TSS and particulate iron via settling. Jar test results demonstrated that chemical addition enhances flocculant formation, reduces settling time, and improves clarity of treated water. Based on comparative screening of 12 flocculants and coagulants at a range of chemical doses, ClearTech CTI 4900 flocculant was recommended for field testing at a dosage of 15 milligrams per liter (mg/L). Additional jar testing is not planned during the wetland demonstration, although turbidity measurements and visual observations will be used to optimize the flocculant dosage.

Sampling and monitoring will be conducted at SB No. 1 during the colonization phase to evaluate treatment performance, determine changes in water quality parameters, and evaluate heat loss through the reactor. The following operational parameters and samples will be collected from SB No. 1 to evaluate treatment performance:

- Weekly field observations and system inspections.
- Weekly influent and effluent samples (flow diversion box [FDB] and SB1EFF, respectively) for analysis of total and dissolved metals, TSS, sulfate, and total dissolved sulfide.
- Continuous monitoring of influent flow rate using a factory calibrated electromagnetic flowmeter (FM01, located inline with the influent piping from the FDB to inlet to SB No. 1); influent and effluent water quality parameters using data-logging sondes deployed at FDB and SB1EFF, respectively; and influent and effluent temperatures (SB1T01 and SB1T02, respectively).

Additionally, chemical dosing rates into SB No. 1 will be monitored and adjusted to ensure the optimal chemical dosing rate is used for flocculation, coagulation, and settling of suspended solids.

4.1.3 Wetland Demonstration Testing

During the initial wetland demonstration test trial, the flow rate through SB No. 1 will remain at approximately 30 gpm (nominal HRT of about 17.6 hours). Once hydraulic equilibrium through the system has been achieved and sufficient data has been collected at this flow rate, the influent flow rate will be modified. The flow rate will be increased or decreased in consultation with the Rico project team to assess removal of solids in SB No. 1 under different flow conditions.

The monitoring and sampling that will be conducted at SB No. 1 during all wetland demonstration flow rates are similar to that to be conducted during the colonization phase, although frequency will be reduced. The following operational parameters and samples will be collected from SB No. 1 to evaluate treatment performance during the wetland demonstration:

- Field observations and system inspections to be conducted approximately twice per month.

- Influent and effluent samples (FDB and SB1EFF, respectively) will be collected approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, and total dissolved sulfide.

- Continuous monitoring of influent flow rate using a factory calibrated electromagnetic flowmeter (FM01); influent and effluent water quality parameters using data-logging sondes deployed at FDB and SB1EFF, respectively; and influent and effluent temperatures (SB1T01 and SB1T02, respectively).

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Additionally, a tracer test using rhodamine dye may be conducted at SB No. 1. A pulse injection of a known quantity of rhodamine dye would be introduce to the influent of SB No. 1 (at location FDB), and the rhodamine concentration at the effluent (SB1EFF) would be monitored over time. Tracer data would be used to verify the mean HRT, to assess the residence time distribution (RTD), and to determine if the outlet control structure prevents short-circuiting through SB No. 1. Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.1.4 Post-Wetland Demonstration

After the wetland demonstration has been completed, SB No. 1 will be drained and the sludge volume will be estimated. Sludge samples will be obtained from six locations along the bottom of the settling basin (SB1SL1A through SB1SL6A, Figure B-2). Sludge samples will be analyzed for acid-soluble metals content and density to evaluate the material that is removed via sedimentation during the wetland demonstration.

4.2 POLISHING SURFACE FLOW WETLAND

The polishing SF wetland will be located immediately downstream of SB No. 1 in the wetland demonstration treatment train (Figure B-1). The primary treatment objective for the polishing SF wetland is to provide secondary removal of TSS and particulate Fe from the wetland demonstration influent. This unit process will utilize several mechanisms to remove particulate Fe, including sedimentation of particulates; sorption to plant and organic materials; and potential settling after flocculation with plant-produced natural flocculants. The polishing SF wetland is designed to reduce particulate Fe from the SB No. 1 effluent (estimated to be about 3 mg/L) to target total Fe concentrations of less than 0.5 mg/L entering the SSF wetland. Reduction of particulate Fe and TSS through this unit process will minimize interferences with metals removal processes in the SSF wetland and the rock drain and will reduce the potential for particulates to clog the SSF wetland matrix material.

The specific treatability study objectives for the polishing SF wetland and the methods by which these objectives will be evaluated are presented in Table B-3. To achieve these objectives, the field sampling and monitoring activities that are presented in Table B-4 will be completed. The sampling and monitoring locations for the polishing SF wetland, including the locations of influent and effluent temperature loggers, are shown on Figure B-3.

The following subsections summarize the operations and field activities that will be completed for the polishing SF wetland.

4.2.1 Baseline

A post-construction survey of the polishing SF wetland will be completed to determine as-built conditions.

4.2.2 Colonization Phase

During the colonization phase, the polishing SF wetland will receive effluent from SB No. 1. The flow rate through the polishing SF wetland will be equal to the effluent flow rate from SB No. 1. The flow rate will be set to the design flow rate of 30 gpm, which will result in a nominal HRT of about 5.6 hours for the polishing SF wetland. Although colonization of the polishing SF wetland with wetland plants may improve treatment effectiveness, these plants are not expected to grow substantially during the colonization period. However, the polishing SF wetland will be monitored during the colonization phase to provide additional data for evaluation of this unit process and to provide influent data for the SSF wetland.

Sampling and monitoring will be conducted at the polishing SF wetland during the colonization phase to evaluate treatment performance, determine changes in water quality parameters, and evaluate heat loss through the reactor. The following operational parameters and samples will be collected from the polishing SF wetland during the colonization phase (Table B-4):

- Weekly field observations and system inspections.
- Weekly influent and effluent samples (SB1EFF and PSFWEFF, respectively) for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, total organic carbon (TOC), and biochemical oxygen demand (BOD).
- Monthly influent and effluent samples (SB1EFF and PSFWEFF, respectively) for analysis of nutrients (nitrogen and phosphorus).
- Continuous monitoring of influent and effluent water quality parameters using data-logging sondes deployed at SB1EFF and PSFWEFF, respectively; and influent and effluent temperatures (PSFWT01 and PSFWT02, respectively).

4.2.3 Wetland Demonstration Testing

For the initial wetland demonstration test trial, the flow rate through polishing SF wetland will remain at approximately 30 gpm (nominal HRT of about 5.6 hours). Once hydraulic equilibrium through the entire system has been achieved and sufficient data has been collected at this flow rate, the system influent flow rate and thus the flow rate through the polishing SF wetland will be modified. The flow rate will be increased or decreased in consultation with the Rico project team to further assess removal of TSS and particulate Fe in the polishing SF wetland.

The monitoring and sampling that will be conducted at the polishing SF wetland during all wetland demonstration flow rates are similar to the colonization phase, with reduced frequencies. The following operational parameters and samples will be collected from the polishing SF wetland to evaluate treatment performance of this unit process during the wetland demonstration (Table B-4):

- Field observations and system inspections to be conducted approximately twice per month.
- Influent and effluent samples (SB1EFF and PSFWEFF, respectively) will be taken approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.
- Monthly influent and effluent samples (SB1EFF and PSFWEFF, respectively) for analysis of nutrients (nitrogen and phosphorus).
- Continuous monitoring of influent and effluent water quality parameters using data-logging sondes deployed at SB1EFF and PSFWEFF, respectively; and influent and effluent temperatures (PSFWT01 and PSFWT02, respectively).

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Additionally, a tracer test using rhodamine dye may be conducted at the polishing SF wetland. A pulse injection of a known quantity of rhodamine dye would be introduce to the influent of the polishing SF wetland (SB1EFF), and the rhodamine concentration at the effluent (PSFWEFF) would be monitored over time. Tracer data would be used to assess the hydraulic characteristics of the polishing SF wetland, specifically the RTD. Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.2.4 Post-Wetland Demonstration

No post-wetland demonstration sampling or testing will be conducted for the polishing SF wetland.

4.3 SUBSURFACE FLOW WETLAND

The SSF wetland will be located downstream of the polishing SF wetland (Figure B-1). The primary objectives for the SSF wetland are to remove dissolved Cd and Zn from the St. Louis Tunnel discharge. The wetland demonstration will be used to determine if a subsurface flow wetland receiving pre-treated mine water can utilize sulfide generated by SRB to precipitate Cd and Zn as metal sulfides. The influent to the SSF wetland will be pre-treated by SB No. 1 and the polishing SF wetland and is expected to have low particulate Fe and TSS concentrations.

The specific treatability study objectives for the SSF wetland and the methods by which these objectives will be evaluated are presented in Table B-5. To achieve these objectives, the field sampling and monitoring activities that are summarized in Table B-6 will be completed. Figure B-4 shows the sampling and monitoring locations for the SSF wetland, including the locations of water quality monitoring ports, the influent and effluent pressure transducers with temperature loggers, the effluent sonde location, matrix sampling locations, , and locations of temperature profile probes. The SSF wetland influent samples will be taken and influent water quality parameters will be measured at the effluent of the polishing SF wetland (sample location PSFWEFF, shown on Figure B-3), immediately upstream of the SSF wetland.

The following subsections summarize the operations and field activities that will be completed for the SSF wetland.

4.3.1 Baseline

After the post-construction survey, baseline measurements will be used to establish the initial chemical and hydraulic characteristics of the SSF wetland matrix. Baseline matrix samples will be taken from up to 12 locations throughout the SSF wetland to determine initial metals concentrations and physical properties (i.e., porosity and permeability). The baseline total depth of each SSF wetland monitoring ports (SSFWMP01 through SSFWMP11) will be measured to allow determination of sediment accumulation throughout the wetland demonstration. Baseline surveys will also be conducted to determine elevations of monitoring ports and the matrix material surface.

Once the flow through the system is initiated (which will occur at the end of the baseline phase), influent and effluent water levels and temperatures will be continuously monitored using pressure transducers (see SOP 14.0). Additionally, slug testing at each SSF wetland monitoring ports will be completed to determine the baseline hydraulic conductivity of the matrix in accordance with SOP 11.0. Baseline water levels will be used for comparison throughout the wetland demonstration; increases in water levels over time may indicate that the hydraulic capacity of the SSF wetland has been exceeded or that the permeability of matrix material is decreasing due to clogging with particulate material, biomass, or precipitates.

4.3.2 Colonization Phase

During the colonization phase, the flow rate through the SSF wetland will be set to the design flow rate of 30 gpm, which will result in a nominal HRT of about 17.2 hours for this unit process. The flow rate into the SSF wetland will be equal to the effluent flow rate from the polishing SF wetland. Colonization is a critical phase for the SSF wetland and will allow growth and adaptation of SRB in the SSF wetland matrix material. Continuous monitoring of water quality parameters will be used to determine when the SSF wetland is sufficiently colonized. Additionally, water samples will be obtained to determine the effects of colonization on removal of the target metals (Cd and Zn) and to provide influent data for the aeration channel.

Sampling and monitoring will be conducted at the SSF wetland during the colonization phase to evaluate treatment performance, determine changes in water quality parameters, evaluate heat loss, and monitor water levels. The following operational parameters and samples will be collected from the SSF wetland during the colonization phase (Table B-6):

- Weekly field observations and system inspections.
- Weekly influent, midpoint, and effluent samples (PSFWEFF, SSFWMP06, and SSFWMP11, respectively) for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.
- Weekly water quality measurements, weekly water level measurements (using manual electric water level sounders), and monthly total depth measurements at all 11 SSF wetland monitoring ports (SSFWMP01 through SSFWMP11).
- Monthly influent and effluent samples (PSFWEFF and SSFWMP11, respectively) for analysis of nutrients (nitrogen and phosphorus).
- Continuous monitoring of influent and effluent water quality parameters using data-logging sondes deployed at PSFWEFF and SSFWMP11, respectively; influent and effluent water levels and temperatures using pressure transducers (SSFWMP01 and SSFWMP11, respectively); and vertical profiles of matrix temperatures (SSFWTPP01 through SSFWTPP04).
- Slug testing at each SSF wetland monitoring port (SSFWMP01 through SSFWMP11) to determine initial hydraulic conductivity through the SSF wetland matrix.

Additionally, a tracer test using a conservative salt (sodium bromide or lithium chloride) may be conducted in the SSF wetland. A pulse injection of a known quantity of salt would be introduced to the influent of the SSF wetland (at PSFWEFF to allow distribution across the upgradient end of the SSF wetland), and the concentration at each monitoring port (SSFWMP01 through SSFWMP11) and the effluent (ACINF) would be monitored as changes in SEC over time. Results of this initial tracer test would be considered the baseline hydraulic characteristics of the SSF wetland and would be used to evaluate whether the entire volume of the SSF wetland is being utilized for treatment. Results of any additional SSF wetland tracer tests would be compared to the results of this baseline tracer test to evaluate changes in nominal HRT, RTD, and flow characteristics due to operation of the system. Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.3.3 Wetland Demonstration Testing

For the initial wetland demonstration test trial, the flow rate through SSF wetland will remain at approximately 30 gpm. Any modification to the system flow will also alter the flow rate through the SSF wetland and will allow an evaluation of Cd and Zn removal and changes in hydraulic the hydraulic response (i.e., water levels and hydraulic gradient) to different hydraulic loading conditions. The 11 monitoring ports in the SSF wetland will also allow evaluation of different SSF wetland residence times without altering the system flow rate.

The monitoring and sampling that will be conducted at the SSF wetland during all wetland demonstration flow rates are similar to that to be conducted during the colonization phase; however, the frequency will be decreased. The following operational parameters and samples will be collected from the SSF wetland to evaluate treatment performance during the wetland demonstration (Table B-6):

- Field observations and system inspections to be conducted approximately twice per month.
- Influent, midpoint, and effluent samples (PSFWEFF, SSFWMP06, and SSFWMP11, respectively) to be taken approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.
- Water quality parameters and water levels at all 11 SSF wetland monitoring ports (SSFWMP01 through SSFWMP11) to be measured approximately twice per month.
- Monthly total depth at all 11 SSF wetland monitoring ports (SSFWMP01 through SSFWMP11).
- Monthly influent and effluent samples (PSFWEFF and SSFWMP11, respectively) for analysis of nutrients (nitrogen and phosphorus).

- Continuous monitoring influent and effluent water quality parameters using data-logging sondes deployed at PSFWEFF and SSFWMP11, respectively; influent and effluent water levels and temperatures using pressure transducers (SSFWMP01 and SSFWMP11, respectively); and vertical profiles of matrix temperatures (SSFWTPP01 through SSFWTPP04).

- Slug testing at each SSF wetland monitoring ports (SSFWMP01 through SSFWMP11) to determine changes in hydraulic conductivity of the SSF wetland matrix over the course of the wetland demonstration.

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Tracer tests using a conservative salt may also be conducted in the SSF wetland for each wetland demonstration flow rate. A pulse injection of a known quantity of salt would be introduced to the influent of the SSF wetland (PSFWEFF), and the concentration at each monitoring port (SSFWMP01 and SSFWMP11) and the effluent (ACINF) would be monitored as changes in SEC over time. Hydraulic characteristics of the SSF wetland as determined from the wetland demonstration tracer tests would be compared to the baseline hydraulic characteristics of the SSF wetland to determine changes due to operation of the system. Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.3.4 Post-Wetland Demonstration

Post-wetland demonstration sampling and testing will be used to evaluate the final chemical and hydraulic characteristics of the SSF wetland matrix. Matrix samples will be collected from up to 12 locations throughout the SSF wetland to determine the accumulated metals concentrations and changes in porosity and permeability due to operation of the wetland demonstration. Results of these activities will be used to evaluate potential full-scale operation of a SSF wetland, determine the hydraulic feasibility of such a system, and estimate longevity and maintenance requirements to maintain flow through a SSF wetland.

4.4 AERATION CHANNEL

The aeration channel will be placed immediately downstream of the SSF wetland (Figure B-1) and will receive effluent from the SSF wetland, which is expected to have low dissolved oxygen concentrations and relatively high concentrations of oxygen-demanding material (i.e., sulfide and BOD). The aeration channel is designed to increase dissolved oxygen concentrations by reaerating the SSF wetland effluent and to decrease concentrations oxygen-demanding species via oxidation of sulfide to elemental sulfur; settling of precipitated sulfur and sloughed biomass;

and aerobic biological oxidation of BOD. The aeration channel will also increase DO concentrations in the treated mine water, thereby promoting Mn oxidation in the aerobic rock drain, which follows the aeration channel.

The specific treatability study objectives for the aeration channel and the methods by which these objectives will be evaluated are presented in Table B-7. To achieve these objectives, the field sampling and monitoring activities that are summarized in Table B-8 will be completed. Figure B-5 shows the sampling and monitoring locations for the aeration channel, including the influent and effluent sampling locations, the effluent sonde location, and matrix sampling locations. Influent samples and influent water quality parameters for the aeration channel will be taken at the effluent monitoring port of the SSF wetland (sample location SSFWMP11, shown on Figure B-4), immediately upstream of the aeration channel.

The following subsections summarize the major elements of the field sampling plan (Table B-8) that will be completed to meet the specific study objectives for the aeration channel.

4.4.1 Baseline

A post-construction survey will be conducted to determine as-built conditions for the aeration channel.

4.4.2 Colonization Phase

During the colonization phase, the flow rate through the aeration channel will be equal to effluent flow rate from the SSF wetland. The expected flow rate of 30 gpm will yield a nominal HRT of about 0.15 hour for the aeration channel. The aeration channel will receive effluent from the SSF wetland that is anticipated to have relatively high BOD and sulfide concentrations. Although aeration channel will not require colonization with microorganisms that remove metals, the aerobic conditions within the aeration channel are likely to stimulate biofilm growth on the rock surfaces. These biofilm microorganisms are expected to oxidize BOD and precipitate elemental sulfur by oxidation of sulfide as the SSF wetland effluent is reaerated.

Sampling and monitoring will be conducted at the aeration channel during the colonization phase to evaluate treatment performance, determine changes in water quality parameters, evaluate heat loss, and monitor water levels. The following operational parameters and samples will be collected from the aeration channel during the colonization phase (Table B-8):

- Weekly field observations and system inspections.

- Weekly influent and effluent samples (SSFWMP11 and ACEFF, respectively) for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.

- Weekly water quality measurements at ACMID.

- Monthly influent and effluent samples (SSFWMP11 and ACEFF, respectively) for analysis of nutrients (nitrogen and phosphorus).

- Continuous monitoring of influent and effluent water quality parameters using data-logging sondes deployed at SSFWMP11 and ACEFF, respectively.

4.4.3 Wetland Demonstration Testing

For the initial wetland demonstration test trial, the flow rate through aeration channel will remain at approximately 30 gpm. Any modification to the system flow will also alter the flow rate through the aeration channel and will allow an evaluation of reaeration under different hydraulic loading conditions. The mid-channel monitoring location (ACMID) will also allow evaluation of different water quality parameters (particularly DO) at a residence time of about half that of the entire aeration channel, without altering the system flow rate.

The monitoring and sampling that will be conducted at the aeration channel during all wetland demonstration flow rates are similar to the colonization phase, although the frequency will be decreased. The following operational parameters and samples will be collected from the aeration channel to evaluate treatment performance during the wetland demonstration (Table B-8):

- Field observations and system inspections will be conducted approximately twice per month.

- Influent and effluent samples (SSFWMP11 and ACEFF, respectively) will be taken approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.

- Water quality parameters measured approximately twice per month at ACMID.

- Monthly influent and effluent samples (SSFWMP11 and ACEFF, respectively) for analysis of nutrients (nitrogen and phosphorus).

- Continuous monitoring of influent and effluent water quality parameters using data-logging sondes deployed at SSFWMP11 and ACEFF, respectively.

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Additionally, a tracer test using rhodamine may be conducted in the aeration channel during the wetland demonstration to evaluate nominal HRT, RTD, and flow characteristics. Tracer would be added to the aeration channel influent (ACINF) and the response would be measured at the aeration channel effluent (ACEFF). Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.4.4 Post-Wetland Demonstration

Post-wetland demonstration sampling and testing will be used to determine the concentrations of metals in any sediment that accumulates in the aeration channel. Sediment samples will be obtained from six locations (ACM1A through ACM6A) along the length of the aeration channel and analyzed for acid soluble metals.

4.5 ROCK DRAIN

The aerobic rock drain will be placed immediately downstream of the aeration channel (Figure B-1). The rock drain will receive reaerated mine water from the aeration channel and will promote aerobic microbial oxidation of dissolved Mn to insoluble MnO_2. The primary treatment objective for the rock drain is to reduce the concentration of dissolved Mn in the St. Louis Tunnel discharge.

The specific wetland demonstration objectives for the rock drain and the methods by which these objectives will be evaluated are presented in Table B-9. To achieve these objectives, the field sampling and monitoring activities that are summarized in Table B-10 will be completed. Figure B-5 shows the sampling and monitoring locations for the rock drain, including the influent and effluent sampling locations, monitoring ports along the rock drain, the influent and effluent pressure transducers with temperature loggers, the effluent sonde location (RDEFF), matrix sampling locations, and locations of temperature profile probes. Influent samples and influent water quality parameters for the rock drain will be taken at the effluent monitoring port of the aeration channel (sample location ACEFF, shown on Figure B-5), immediately upstream of the rock drain. The rock drain effluent flow rate will be monitored at FM04, and rock drain effluent will be discharged to Pond 18.

The following subsections summarize the major elements of the field sampling plan that will be completed to meet the specific treatability study objectives for the aeration channel.

4.5.1 Baseline

After the post-construction survey, baseline measurements will be used to establish the initial chemical characteristics of the rock drain matrix. Baseline matrix samples will be taken from up to 6 locations throughout the rock drain (Figure B-5) to determine initial metals concentrations. The baseline total depth of each rock drain monitoring ports (RDMP01 through RDMP06) will be measured to allow determination of sediment accumulation throughout the wetland demonstration.

4.5.2 Colonization Phase

During the colonization phase, the rock drain will receive effluent from the aeration channel at a flow rate of about 30 gpm, which will result in a nominal HRT of about 15.7 hours for the rock drain. Colonization is critical for the rock drain to establish a population of Mn-oxidizing microorganisms. Water samples from the rock drain will be analyzed to monitor colonization and assess the removal of Mn.

Sampling and monitoring will be conducted at the rock drain during the colonization phase to evaluate treatment performance, determine changes in water quality parameters, evaluate heat loss, and monitor water levels. The following operational parameters and samples will be collected from the rock drain during the colonization phase (Table B-10):

- Weekly field observations and system inspections.
- Weekly influent, midpoint, and effluent samples (ACEFF, RDMP04, and RDEFF, respectively) for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.
- Weekly water quality measurements, weekly water level measurements, and monthly total depth measurements at all 6 rock drain monitoring ports (RDMP01 through RDMP06).
- Monthly influent and effluent samples (ACEFF and RDEFF, respectively) for analysis of nutrients (nitrogen and phosphorus).
- A monthly effluent sample (RDEFF) for analysis of the discharge to Pond 18, including comprehensive analysis of total and dissolved metals, total chloride, total cyanide, total sulfide, and TOC.
- Monthly total depth measurements of monitoring ports (RDMP01 through RDMP06).
- Continuous monitoring of influent and effluent water quality parameters using data logging sondes deployed at ACEFF and RDEFF, respectively; influent and effluent temperatures and water levels (pressure transducers located inside RDMP01 and

RDMP06, respectively); vertical profiles of rock drain matrix temperatures (RDTPP01 and RDTPP02); and effluent flow rate using a factory calibrated electromagnetic flowmeter (FM04, located inline with the effluent piping from the rock drain to Pond 15).

4.5.3 Wetland Demonstration Testing

For the initial wetland demonstration test trial, the flow rate through rock drain will remain at approximately 30 gpm. Any modification to the system flow will also alter the flow rate through the rock drain and will allow an evaluation of Mn removal and hydraulic response under different hydraulic loading conditions. The monitoring ports within the rock drain (RDMP01 through RDMP06) will allow evaluation of water quality parameters, water levels, and Mn removal at various residence times within the rock drain, without altering the system flow rate or the HRT of the rock drain.

The monitoring and sampling that will be conducted at the rock drain at all wetland demonstration flow rates are similar to that to be conducted during the colonization phase, although the frequency will be decreased. The following operational parameters and samples will be collected from the rock drain to evaluate treatment performance during the wetland demonstration (Table B-10):

- Field observations and system inspections will be conducted approximately twice per month.
- Influent, midpoint, and effluent samples (ACEFF, RDMP04, and RDEFF, respectively) will be taken approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, total dissolved sulfide, TOC, and BOD.
- Water quality parameters and water levels to be measured twice per month at all 6 rock drain monitoring ports (RDMP01 through RDMP06).
- Monthly influent and effluent samples (ACEFF and RDEFF, respectively) for analysis of nutrients (nitrogen and phosphorus).
- Monthly total depth at all at all 6 rock drain monitoring ports (RDMP01 through RDMP06).
- A monthly effluent sample (RDEFF) for analysis of the discharge to Pond 18, including comprehensive analysis of total and dissolved metals, total chloride, total cyanide, total sulfide, and TOC.
- Continuous monitoring of influent and effluent water quality parameters using data logging sondes deployed at ACEFF and RDEFF, respectively; influent and effluent temperatures and water levels (pressure transducers located inside RDMP01 and RDMP06, respectively); vertical profiles of rock drain matrix temperatures (RDTPP01

and RDTPP02); and effluent flow rate using a factory calibrated electromagnetic flowmeter (FM04).

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Additionally, a tracer test using rhodamine may be conducted in the rock drain during the wetland demonstration to evaluate nominal HRT, RTD, and flow characteristics. A known quantity of the tracer would be injected to the rock drain influent (ACEFF) and the response would be measured at rock drain monitoring ports (RDMP01 through RDMP06) and the rock drain effluent (RDEFF). Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.5.4 Post-Wetland Demonstration

Post-wetland demonstration sampling and testing will be used to determine the concentrations of metals that accumulate on rock drain media. Rock drain matrix samples will be obtained from six locations (RDM1A through RDM6A) throughout the rock drain channel and analyzed for acid soluble metals. Additionally, visual observations will be made of the rock drain media to assess deposition of oxidized Mn and growth of Mn-oxidizing bacteria.

4.6 SETTLING BASIN NUMBER 2

SB No. 2 will be a standalone treatment unit where technologies for removal of suspended solids and particulate Fe can be tested without altering the performance of the wetland demonstration treatment train. SB No. 2 will be located adjacent to SB No. 1 (Figures B-1 and B-2) and will receive a slipstream of influent water from the wetland demonstration influent flow diversion structure. Treated effluent from SB No. 2 will be discharged directly to Pond 18.

The primary treatment objective for SB No. 2 is to evaluate the removal of suspended solids and particulate Fe from the St. Louis Tunnel discharge using Gunderboom® passive treatment technology. Gunderboom® treatment permeable curtains will be installed 20 feet and 60 feet from the inlet to the SB No. 2.

The specific treatability study objectives for SB No. 2 and the methods by which these objectives will be evaluated are presented in Table B-11. To achieve these objectives, the field sampling and monitoring activities that are summarized in Table B-12 will be completed. Figure B-2 shows the SB No. 2 sampling and monitoring locations, including the influent and effluent sampling locations, post-test sludge sampling locations, and influent and effluent temperature logger locations. Influent samples and influent water quality parameters for the rock drain will be taken from the flow diversion box (sample location FDB, shown on Figure B-2). The SB No. 2 influent flow rate will be monitored at FM02 using a factory calibrated electromagnetic flowmeter, and the effluent will be discharged to Pond 18.

The following sections summarize the major elements of the field sampling plan that will be completed to meet the specific study objectives for SB No. 2.

4.6.1 Baseline

A post-construction survey will be conducted to determine as-built conditions of SB No. 2.

4.6.2 Colonization Phase

No field sampling or testing activities are planned for SB No. 2 during the colonization phase. SB No. 2 relies on physical rather than biological removal mechanisms; thus, no colonization activities are required or will be conducted.

4.6.3 Wetland Demonstration Testing

Removal of suspended solids and particulate Fe with the Gunderboom® passive treatment technology will be tested independently of the main wetland demonstration treatment train in SB No. 2. SB No. 2 will have its own flow control box and influent flowmeter (FM02; Figure B-2). During solids removal testing, the influent flow rate will be set to the manufacturer's recommended operation conditions. For an influent flow rate of 30 gpm, the nominal HRT for SB No. 2 will be 17.6 hours. The flow rate through SB No. 2 may be varied to assess solids removal under different operating conditions once steady state conditions are approximated and sufficient data have been gathered to satisfy the study objectives for this unit process.

The following monitoring and sampling will be conducted at SB No. 2 to evaluate treatment performance at each operating condition:

- Field observations and system inspections will be conducted approximately twice per month.
- Influent and effluent samples (FDB and SB2EFF, respectively) will be taken approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, and total dissolved sulfide.
- Effluent (SB2EFF) water quality parameters will be measured twice per month at the same time effluent samples are taken.

- A monthly effluent sample (SB2EFF) will be taken for analysis of the discharge to Pond 18, including comprehensive analysis of total and dissolved metals, total chloride, total cyanide, total sulfide, and TOC.

- Continuous monitoring of influent and effluent temperatures (SB2T01 and SB2T02, respectively); influent flow rate using a factory calibrated electromagnetic flowmeter (FM02, located inline with the influent piping from the FDB to the SB No. 2 inlet); and influent water quality parameters (FDB).

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Additionally, a tracer test using rhodamine dye may be conducted at SB No. 2 to verify the mean HRT and to assess the RTD. A pulse injection of a known quantity of rhodamine dye would be introduce to the influent of SB No. 2 (at location FDB), and the rhodamine concentration at the effluent (SB2EFF) would be monitored over time. Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.6.4 Post-Wetland Demonstration

After the wetland demonstration has been completed, SB No. 2 will be drained and the sludge volume will be estimated. Sludge samples will be obtained from six locations along the bottom of SB No. 2 (SB2SL1A through SB2SL6A, Figure B-2). Sludge samples will be analyzed for acid-soluble metals content and density to evaluate the material that is removed via sedimentation during the wetland demonstration.

4.7 STANDALONE SURFACE FLOW WETLAND

The standalone SF wetland will receive a slipstream of influent water from the wetland demonstration influent flow diversion structure (FDB in Figure B-6) and will discharge treated water directly to Pond 18. The standalone SF wetland will not be part of the main Wetland Demonstration treatment train. The primary treatment objective for this unit process is to determine if a SF wetland is feasible as a primary Fe removal process. The treatability study will evaluate heat loss during winter operation and passive removal of suspended solids and particulate Fe from the St. Louis Tunnel discharge without primary treatment using a settling basin.

The specific treatability study objectives for the standalone SF wetland and the methods by which these objectives will be evaluated are presented in Table B-13. The field sampling and monitoring activities that are summarized in Table B-14 will be completed to achieve these objectives. Figure B-6 shows the sampling and monitoring locations for the standalone SF wetland, including the influent and effluent sampling locations, and influent and effluent temperature logger locations. Influent samples and influent water quality parameters for the standalone SF wetland will be taken from the flow diversion box (sample location FDB, shown on Figure B-6). The standalone SF wetland influent flow rate will be monitored at FM03 using a factory calibrated electromagnetic flowmeter, and treated effluent will be discharged to Pond 18.

The following subsections summarize the major elements of the field sampling plan that will be completed to meet the specific study objectives for the standalone SF wetland.

4.7.1 Baseline

A post-construction survey will be conducted to determine as-built conditions of the standalone SF Wetland.

4.7.2 Colonization Phase

Visual observations of the standalone SF wetland will be made during the colonization phase. The standalone SF wetland will rely on multiple removal mechanisms, including removal with wetland plants. Thus, the colonization phase will focus on growth of water sedges or other wetland plants. No sampling or monitoring will be conducted at the standalone SF wetland during the colonization phase.

4.7.3 Wetland Demonstration Testing

Because of its independent construction and flow control, the flow rate through the standalone SF wetland can be varied to assess particulate removals under different operating conditions. Removal of suspended solids and particulate Fe in the standalone SF wetland will be tested at several flow rates, without the addition of a flocculant. Contaminant removals at different flow rates will be compared to a published Fe removal rate of 4 grams per square meter per day ($g/m^2/d$; (Hedin, 2008) to determine if this is a reasonable design parameter for use at the site. The influent flow rate will be modified only after steady state conditions are approximated and after sufficient data have been gathered to satisfy the study objectives for the standalone SF wetland.

The following monitoring and sampling will be conducted at the standalone SF wetland to evaluate treatment performance at each operating condition:

- Field observations and system inspections will be conducted approximately twice per month.

- Influent and effluent samples (FDB and SWFEFF, respectively) will be taken approximately twice per month for analysis of total and dissolved metals, TSS, sulfate, and total dissolved sulfide.

- Effluent (SWFEFF) water quality parameters will be measured twice per month at the same time effluent samples are taken.

- A monthly effluent sample (SWFEFF) will be taken for analysis of the discharge to Pond 18, including comprehensive analysis of total and dissolved metals, total chloride, total cyanide, total sulfide, and TOC.

- Continuous monitoring of influent and effluent temperatures (SFWT01 and SFWT02, respectively); influent flow rate using a factory calibrated electromagnetic flowmeter (FM03, located inline with the influent piping from the FDB to the inlet to standalone SF wetland); and influent water quality parameters (FDB).

The actual sampling frequencies may be varied to due site conditions, changing flow rates, or monitoring observations. Sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.

Additionally, a tracer test using rhodamine dye may be conducted at the standalone SF wetland to assess hydraulic characteristics. A pulse injection of a known quantity of rhodamine dye would be introduced to the influent of SB No. 2 (at location FDB), and the rhodamine concentration at the effluent (SB2EFF) would be monitored over time. Results of the tracer test would be used to verify the mean HRT and to assess the RTD of the reactor. Additional details of tracer testing are provided in Section 6 and in SOP 16.0.

4.7.4 Post-Wetland Demonstration

No post-wetland demonstration sampling or testing is planned for the standalone SF wetland.

5.0 HYDROGEN SULFIDE MONITORING

This section describes the H_2S monitoring activities that will be conducted as part of the wetland demonstration to protect worker safety, to protect the general public, and to gather data to evaluate design and engineering controls for the full-scale system. More specifically, the H_2S monitoring objectives are as follows:

- Continuously monitor and data log the H_2S concentrations from the SSF wetland effluent at the inlet to the aeration channel to protect on-site workers.

- Continuously monitor and data log the H_2S concentrations on the outer perimeter of the aeration channel to protect the general public.

- Continuously monitoring and data log H_2S concentrations at the inlet to the aeration channel near the ground surface (where concentrations are expected to be the highest) to estimate maximum H_2S emission rates.

- Evaluate how environmental conditions such as temperature, barometric pressure, and wind speed and direction affect concentrations at the proposed monitoring locations.

- Perform surveys to quantify H_2S concentrations around the perimeter of the SSF wetland, aeration channel, and rock drain and near the monitoring locations of these unit processes.

These data objectives will be obtained by installing a fixed H_2S monitoring system and performing routine monthly H_2S surveys. The fixed H_2S monitoring system will be used to monitor the expected highest concentrations at the inlet to the aeration channel where SSF wetland discharge is aerated and evaluate how environmental conditions affect H_2S concentrations in the breathing zone at the inlet to the aeration channel and perimeter of the aeration channel.

The fixed H_2S monitoring system will allow an evaluation of the engineering controls that will need to be implemented as part of the inlet control structure for the aeration channel. The aeration channel inlet includes an Agridrain structure where water will flow upwards through a Durapac plastic matrix and cascade over a weir into the aeration channel. The purpose of this design is to allow the sulfide-rich water to move up through a water column with a variable oxygen gradient to promote oxidation to sulfur. The Durapac plastic media will provide additional surface area and attachment sites for growth of sulfur-oxidizing bacteria, which will promote rapid conversion of sulfide to elemental sulfur. This engineering control could reduce H_2S emissions from the aeration channel inlet and the aeration channel itself. As part of this engineering control evaluation, the system will be operated with and without the Durapac plastic media to assess changes in H_2S concentrations. In addition, other engineered media maybe installed into the inlet control structure to evaluate the changes in H_2S concentrations based on the different media types.

Routine monthly H_2S surveys will be completed to measure the concentrations at the fixed H_2S monitoring locations and around the perimeter of the SSF wetland, aeration channel and rock drain and near associated system monitoring locations of these unit processes. During the monthly surveys, concentrations at the fixed H_2S monitoring devices will be recorded using the multi-gas meter and compared to the real-time readings of the fixed devices to confirm measurements and to assess if the fixed monitoring devices need to be calibrated and/or sensors need to be replaced.

5.1 LOCATIONS

Four fixed H_2S sensors and one sensor controller will be placed at the site; locations are shown in Figure B-1. The controller will be installed in the chemical feed building, and the fixed H_2S sensors will be installed at following four locations:

- H2S01 (Figure B-1) will be installed east of the outlet to the aeration channel adjacent to the access road for protection of the general public.
- H2S02 (Figure B-1) will be installed east of the inlet to the aeration channel adjacent to the access road for protection of the general public.
- H2S03 (Figure B-5) will be installed at the inlet to the aeration channel approximately 4 feet above the ground surface to measure the concentrations in the breathing zone for worker protection.
- H2S04 (Figure B-5) will be installed at the inlet to the aeration channel approximately 1.5 feet above ground surface to measure the maximum concentrations emitted from the aeration channel.

Sensors H2S01 and H2S02 will be located between the SSF wetland and the aeration channel to detect emissions from these unit processes and to provide monitoring to protect workers approaching sampling locations near these unit processes. Sensors H2S03 and H2S04 will be located near the aeration channel influent (ACINF). This location is likely to have the highest H_2S concentrations due to volatilization of H_2S from SSF wetland effluent into ambient air at the aeration channel inlet structure.

The sensors will be connected to a controller installed in the chemical feed building and programmed with alarms. This will allow for personnel to view real-time concentrations at the perimeter of the aeration channel to clear the work area prior to performing work activities.

Monthly H_2S surveys will be conducted to assess concentrations around the perimeter of the SSF wetland, aeration channel, and rock drain and the associated monitoring locations. The monitoring locations include the following:

- Perimeter of the SSF wetland, aeration channel, and rock drain (Figure B-1).
- Influent and effluent monitoring locations of the SSF wetland, aeration channel, and rock drain (PSFWEFF; Figure B-3, SSFWMP11; Figure B-4, ACEFF; Figure B-5, and RDEFF; Figure B-5).
- SSF wetland and rock drain monitoring ports (Figure B-4 and Figure B-5, respectively).

- Fixed H_2S monitoring locations (Figure B-1).

5.2 Monitoring Methods

Four (4) Detcon Model TP-700 H_2S solid state metal oxide semiconductor (MOS) sensors will installed as part of the wetland demonstration fixed monitoring system. The sensors will be connected to a controller installed in the chemical feed building and programmed with alarms. This will allow for personnel to view real-time concentrations at the perimeter of the aeration channel to clear the work area prior to performing work activities. The controller will be set to alarm at 5 parts per million (ppm), at the ceiling level of H_2S at 20 ppm, and at the Immediately Dangerous to Life and Health (IDLH) level at 100 ppm. The data loggers will be programmed to log concentrations every hour and log data when alarms are triggered. The controller is equipped with a programmable alarm system to allow for personnel to view alarm history and real-time concentrations prior to performing monitoring activities in the vicinity of the aeration channel.

During routine inspections, real-time H_2S concentrations at each monitoring location will be recorded and any triggered alarms will be documented. Concentrations will be reviewed prior to performing work activities to confirm concentrations do not exceed the site action level of 5 ppm. Data will also be downloaded from the controller during the routine inspections.

Monthly H_2S surveys will be conducted to measure the concentrations at the fixed H_2S monitoring locations and around the perimeter of the SSF wetland, aeration channel and rock drain and near associated system monitoring locations of these unit processes in the breathing zone. During the monthly surveys, concentrations at the fixed H_2S monitoring devices will be recorded using a calibrated multi-gas meter and compared to the real-time readings of the fixed devices to confirm measurements and to assess if the fixed monitoring devices need to be calibrated and/or sensors need to be replaced.

A summary of the H_2S monitoring activities to be performed during the wetland demonstration testing is presented in Table B-17.

5.3 Data Evaluation and Usage

Downloaded data from the fixed H_2S monitoring devices will be reviewed and analyzed approximately monthly to assess concentrations emitted from the SSF wetland and to monitor concentration in the breathing zone and near the eastern perimeter of the inlet and outlet structures of the aeration channel for the protection of the general public. H_2S data will be correlated with temperature, barometric pressure, wind speed, and wind direction data to assess how concentrations at the monitoring locations are affected by environmental conditions.

In addition, data will be reviewed to assess if the design of the inlet to the aeration channel can reduce H_2S gas emissions from the SSF wetland. In addition, data will be evaluated to assess if the design of the inlet to the aeration channel does reduce H_2S emissions from the SSF wetland.

Data collected during the monthly H_2S surveys will be evaluated approximately monthly to confirm the fixed H_2S sensors are operating appropriately and evaluate if sensor maintenance is required. In addition, data collected will be assessed evaluated to understand if H_2S off-gassing is occurring at other locations within the wetland demonstration treatment system.

H_2S data collected during the wetland demonstration testing will aid in the development of H_2S engineering controls in a full-scale constructed wetland treatment system.

6.0 TRACER TESTING

As mentioned in previous sections and as summarized in Table B-16, tracer testing will be used to evaluate the hydraulic characteristics of several unit processes. Each tracer test will be used to determine the RTD and mean HRT for the unit process using reactor analysis methods from chemical engineering literature (Levenspiel, 1999; Fogler, 2005). Results will be used for interpreting treatability study results and for evaluating hydraulic characteristics of each unit process.

6.1 LOCATIONS AND TIMING

The following tracer tests are proposed, as summarized in Table B-16.

- SB No. 1: one tracer test during the wetland demonstration
- Polishing SF wetland: one tracer test during the wetland demonstration
- SSF wetland: one tracer test during colonization to establish baseline hydraulic characteristics; two tracer tests during the wetland demonstration to assess changes in hydraulic characteristics over time
- Aeration channel: one tracer test during the wetland demonstration
- Rock drain: one tracer test during the wetland demonstration
- SB No. 2: one tracer test during independent operation of this unit process
- Standalone SF wetland: one tracer test during independent operation of this unit process

6.2 METHODOLOGY

Pulse injection tracer testing will be utilized. A known quantity of a conservative tracer will be rapidly injected at the influent of a unit process, and the effluent concentration response will be measured. For the SSF wetland and the rock drain, additional monitoring will be conducted at intermediate monitoring ports within the reactor to verify that flow occurs throughout the reactor and to provide additional data on flow patterns. The mass of injected tracer needs to be high enough to allow detection at the outlet and any intermediate monitoring ports of reactor that is being tested. The mass of tracer to be injected will be estimated using basic transport modeling using assumed and known transport characteristics of each reactor.

The conservative tracers that will be used are rhodamine (a fluorescent dye) and sodium bromide (NaBr) or lithium chloride (LiCl), which are soluble salts. Rhodamine will not be used for tracer tests in the SSF wetland, based on poor recoveries and the non-conservative transport of rhodamine in tracer tests that were conducted in the pilot-scale wetland. Rhodamine will be used in tracer tests in SB No. 1, SB No. 1, the polishing SF wetland, the aeration channel, the rock drain, and the standalone SF wetland. NaBr or LiCl will be used for tracer studies in the SSF wetland. These salts are not expected to be significantly adsorbed or otherwise retarded during transport through the SSF wetland matrix material.

To the extent possible, tracer test monitoring will utilize data logging field instrumentation to assess responses to tracer inputs. When rhodamine is used as the tracer, data logging water quality sondes equipped with calibrated rhodamine sensors will be deployed and used for direct measurement of rhodamine concentrations, according to SOP 3.0. For tracer tests that utilize soluble salts, data logging water quality sondes will be used to monitor changes in SEC over time according to SOP 3.0. Additionally, samples will also be taken for laboratory analysis of the primary ions (sodium, bromide, lithium, and/or chloride) to allow correlation of SEC to concentrations for the purpose of calculating mass balances.

Tracer test procedures are described further in SOP 16.0 – Tracer Study.

6.3 DATA EVALUATION AND USAGE

Tracer test data will be evaluated using standard chemical engineering techniques that are used for analysis of nonideal flow (Levenspiel, 1999; Fogler, 2005). Effluent data will be normalized to determine the RTD of the reactor, and the RTD will yield information about non-ideal flow patterns in the reactor (e.g., dispersion, short-circuiting, dead zones) and the mean HRT. The mean HRT calculated from tracer tests will be compared to the theoretical mean HRT based on reactor dimensions and flow rate as part of the assessment of non-ideal flow characteristics of each unit process. These results will allow predictions of reactor performance, will allow troubleshooting in the event of poor treatment performance, and can be considered in the design of full-scale treatment units.

Effluent concentration data will be combined with flow data to calculate a mass balance on tracer mass leaving the reactor. The mass calculated from this numerical integration will be compared to the known quantity of injected tracer to determine if there are dead zones or other non-ideal flow conditions that cause retention of mass within the reactor. The shape of the RTD curve will also be evaluated to determine if the reactor has preferential flow paths or short-circuiting (comparison of mean HRT to expected HRT).

Tracer test data from the SSF wetland and the rock drain will also include results from intermediate monitoring ports. Although concentration data from intermediate monitoring ports cannot be numerically integrated, the intermediate tracer curves will be used to confirm that flow is evenly distributed throughout the reactor.

For several of the reactors, multiple tracer tests will be completed at different times during the wetland demonstration. RTDs from different phases of the wetland demonstration will be compared to evaluate changes in hydraulic characteristics over time. Excessive accumulation of suspended solids, precipitated metals, or growth of biomass will reduce porosity and hydraulic conductivity, and may also result in the development of preferential flow through a reactor; these developments will be evident when RTDs from different phases are compared.

7.0 QUALITY ASSURANCE PROJECT PLAN

Atlantic Richfield's St. Louis Tunnel Discharge Source Mine Water Treatability Study Quality Assurance Project Plan (QAPP; Atlantic Richfield, 2013b) provides the basis for a more directed and logical QA/QC process for short-term environmental data collection activities associated with treatability studies and treatment option evaluations. Such short term data collection programs are designed to properly collect and evaluate screening and/or definitive data in a limited amount of time without the constraints of a rigorous QA/QC program. For this constructed wetland demonstration, the key organization, personnel training, equipment maintenance, procedures for sample handling, documentation and custody, and requirements for analytical data will be in general accordance with these procedures.

7.1 ANALYTICAL METHODS

The types of samples that will be collected and the analyses that will be conducted to meet the specific objectives for each unit process unit are described in Section 4. Samples will be sent to Pace Analytical Laboratories, Inc. in Lenexa, Kansas (Pace) for testing. Pace is an accredited environmental testing laboratory through the National Environmental Laboratory Accreditation Program (NELAP; Kansas NELAP Certificate No. E-101116). Pace will adhere to the additional quality control requirements set forth in Atlantic Richfield's Technical Requirements for Environmental Laboratory Services (Atlantic Richfield, 2011) for associated testing, which provides quality standards for contracted laboratories performing work for Atlantic Richfield. All samples will be submitted to Pace using proper chain of custody procedures and will be analyzed using the U.S. EPA approved methodologies presented in Table B-15. For all analytical methods, the laboratory will adhere to standard operating procedures and the laboratory Quality Assurance Plan for personnel training, proper instrument operation, standard calibration procedures, calculations, and quality control processes.

7.2 STANDARD OPERATING PROCEDURES

AMEC has developed task-specific SOPs (Attachment B-1) which describe field procedures for monitoring performance of the respective unit processes of the constructed wetland demonstration, including collecting samples for testing purposes. These SOPs cover aspects of the constructed wetland demonstration related to general sampling, sample handling, documentation, and field measurement and testing methods to ensure that all activities are completed consistently and properly documented.

All field personnel will have access to the most recent versions of the field SOPs. Revisions to SOPs are documented in accordance with the referenced QAPP (Atlantic Richfield, 2013b). Project files will be updated accordingly with the most recent versions.

7.3 QUALITY CONTROL SAMPLES

The QAPP provides a mechanism for ongoing control and evaluation of data quality measurements through the use of quality control (QC) materials. QA/QC samples will be collected as part of the overall data quality program.

7.3.1 Laboratory Reagent Blanks

A laboratory reagent blank is contaminant-free reagent water that is prepared and analyzed by the laboratory in the same manner as an environmental sample. Analysis of the reagent blank indicates potential sources of contamination from laboratory procedures. A reagent blank will be analyzed once per every 20 samples, or at least once each day for each respective laboratory test method. Detections of target analytes in the laboratory reagent blank may result in re-extraction or re-analysis of the affected samples. Results of laboratory reagent blanks will be reported in the final laboratory report.

7.3.2 Matrix Spike Samples

Matrix spikes are performed by the analytical laboratory to evaluate the efficiency of the sample extraction and analysis procedures, and are necessary because interference from the sample matrix may have varying impact on the accuracy and precision of the analysis. The matrix spike is prepared by the addition of know quantities of target compounds to an environmental sample. The sample is extracted and analyzed in the same manner as the primary sample. The results of the analysis are compared with the known additions and a matrix spike recovery is calculated, giving an evaluation of the accuracy of the test procedure. Matrix spike recoveries are reviewed to check that they are within acceptable ranges derived by the laboratory for the respective sample matrix and analytical method.

Matrix spikes are performed in duplicate in order to evaluate the precision of the procedures as well as the accuracy. Precision is represented by the agreement (i.e., relative percent difference) between calculated spike recoveries of the matrix spike and duplicate matrix spike samples. Limits for precision are established by the laboratory for the respective sample matrix and analytical method to aid in data evaluation. Data review guidance (USEPA, 2004) establishes that acceptance limits for accuracy and precision for matrix spike samples are to be viewed as goals, not as criteria for rejection of the data. If matrix bias is suspected, the associated data will be evaluated based on the direction of the bias and the intended use of the data.

7.3.3 Field Duplicate Samples

Field duplicate samples will be collected and analyzed to evaluate sampling and analytical precision. Field duplicates are collected and analyzed in the same manner as the primary samples. Agreement between duplicate samples will indicate proper sampling and analytical precision. Field duplicates will be collected from each unit process and analyzed using all methods requested for the primary sample collected. If disagreement is found between field duplicate samples, the associated data will be evaluated and corrective action taken if necessary.

7.4 DATA MANAGEMENT

The data produced during all sample collection activities will be managed to ensure that data are correct, readily available, and of the quality necessary to support the project decisions for each unit process. A relational database using Microsoft Access® software will be maintained with field and laboratory analytical measurements.

7.4.1 Field Data

Data measured by field instruments will be recorded electronically and/or on required field forms. Examples of field documentation forms are included in the SOPs and will be used during all sample collection efforts. The field data will be reviewed to evaluate correctness of the results, completeness of the field records and appropriateness of the field methods employed as described in the referenced QAPP (Atlantic Richfield, 2013b). All field records will be retained in the project files. Field measurements will be stored electronically in the project database.

7.4.2 Laboratory Data

Analytical data will contain the necessary sample results and QC data to evaluate the accuracy and precision. Laboratory results will be provided to AMEC for data verification and evaluation to ensure all data meet the documentation and QC requirements of the BP Laboratory Management Program (Atlantic Richfield, 2011). The laboratory will provide analytical data in electronic format for storage in the project database. The project database will be updated with each new set of data provided by the laboratory.

8.0 IMPLEMENTATION SCHEDULE

All work described in this PMP will be initiated and completed after U.S. EPA approval. Additionally, all sampling and monitoring activities will be completed in coordination with other site activities and in consideration of weather and site access conditions. The monitoring and sampling activities as described in this PMP will start after construction of the demonstration system, which is expected to be completed in November 2013.

The estimated general schedule for post-construction operation of the wetland demonstration is as follows:

- **Phase 1, Baseline**: Baseline surveys and monitoring of the wetland demonstration system will commence after construction is complete. The baseline phase is expected to begin in November 2013 and have a duration of one week.

- **Phase 2, Colonization**: After baseline surveys and monitoring are complete, flow of mine water from the flow diversion box will be introduced to the system. The SSF wetland will be inoculated with a SRB culture and the rock drain will be inoculated with a Mn-oxidizing microbial culture. Colonization is expected to start in November 2013 and have a duration of approximately one month.

- **Phase 3, Wetland Demonstration Testing**: Treatability testing of the wetland demonstration system will commence after the SSF wetland and the rock drain have been sufficiently colonized. The demonstration testing phase will last for at least 12 weeks, from December 2013 through March 2014. Data through early March

2014 will be used to support the Technology(s) Selection Report and the 30-Percent/Conceptual Design Report. The performance monitoring period could then be extended to collect additional data to improve the full-scale design and define the optimal operating conditions for the system.

- **Phase 4, Post-Wetland Demonstration**: This phase will include final monitoring and decommissioning of the wetland demonstration system, after the monitoring and sampling objectives have been satisfied. This final phase will have a duration of approximately one month.

The dates that are presented above are subject to change based on actual field implementation times and weather conditions that may cause delays; the monitoring period may be extended if additional data are needed to define the limits of metals removal over a range of seasonal and operating conditions. All activities that are required to meet the objectives of the wetland demonstration will be completed by early April 2014. The results of the treatability study will be then evaluated and incorporated into the Water Treatment Technology Selection Report.

9.0 REPORTING

Constructed wetland treatability study results will be communicated to the U.S. EPA via the following mechanisms:

1. Regular communications with the Rico project team via teleconference and/or email during startup and operation of the wetland demonstration to discuss operational issues, status of testing, and interim results. Teleconferences may be conducted, as necessary, to keep the project team informed of progress and to work through issues that may arise. Key personnel from Atlantic Richfield and the U.S. EPA will be invited to participate in these calls.

2. A brief report to document construction and startup activities will be prepared and submitted to the U.S. EPA. The report will describe the as-built configuration of the system and describe the colonization of the SSF wetland with SRB and the aerobic rock drain with Mn-oxidizing bacteria. This completion report will be prepared and submitted after startup and colonization of the wetland demonstration have been completed.

3. A Performance Evaluation Report detailing the implementation and results of the wetland demonstration will be prepared and submitted to the U.S. EPA. This report will include an evaluation of results through approximately March 30, 2014, documentation of problems that were encountered and solutions that were developed during the treatability study, and a description of how the results can be used for design and operation of a full-scale constructed wetland system at the site. This report will provide a basis for fully evaluating constructed wetlands as a passive treatment technology.

The wetland demonstration results will be included in a Technology Selection Report, which will evaluate a range of technologies and formulate recommendations for mitigating metals impacts to the Dolores River. If a constructed wetland system is selected as part of the remedy, results of the wetland demonstration will be incorporated into the design process for the full-scale treatment system.

10.0 REFERENCES

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Atlantic Richfield, 2013a, St. Louis Tunnel Discharge Constructed Wetland Demonstration Treatability Study Work Plan, Revision 1. Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01, Dolores County, Colorado, prepared by AMEC, October 9.

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TABLES

TABLE B-1
TREATABILITY STUDY OBJECTIVES FOR SETTLING BASIN NO. 1
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use

Remove suspended solids and particulate Fe upstream of the SSF wetland	Remove suspended solids and particulate Fe upstream of the SSF wetland with the addition of a flocculant or coagulant.	• Influent (FDB) TSS and total Fe and effluent (SB1EFF) TSS and total Fe.	• Compare influent and effluent TSS and concentrations.
			• Compare influent and effluent total Fe concentrations.
				• Determine TSS and total Fe concentration reductions through SB No. 1. Concentrations are reduced when:
				  ○ Effluent TSS < influent TSS
				  ○ Effluent Total Fe < influent total Fe

	Reduce total Fe concentrations from as high as 12 mg/L in the influent to approximately 3 mg/L in the effluent for flow rates within the range of 10 to 50 gpm.	• Influent (FDB) and effluent (SB1EFF) total Fe.
		• Flow rate into SB No. 1 (FM01).
			• Compare influent total Fe concentrations to effluent total Fe concentrations.	• Determine reductions in total Fe concentration through SB No. 1, for the range of tested flow rates.
				• Concentrations are acceptably reduced when:
				  ○ Effluent Total Fe < influent total Fe
				  ○ For influent (FDB) total Fe of up to 12 mg/L, effluent (SB1EFF) total Fe is less than 3 mg/L

	Evaluate the metals removal associated with precipitation and sedimentation of Fe oxides and hydroxides.	• Influent (FDB) and effluent (SB1EFF) total and dissolved metals. • Post-demonstration sludge sampling from 6 locations in SB No. 1 (SB1SL1A through SB1SL6A).	• Mass balances on Fe and other metals to be used to evaluate concurrent metals removals. • Calculate metals removal in SB No.1. Metals removal rate to be calculated as: Removal rate = $Q*(C_{in}-C_{out})$. • Metals concentrations in sludge samples will provide information on metals removed with Fe.	• Information to be used to assess fate of metals in SB No. 1.
	Evaluate the HRT required to achieve the desired effluent Fe concentration.	• Flow rate (Q) into SB No. 1 measured at FM01. • Geometry and water depth in SB No. 1 to calculate water volume (V). • Tracer study results.	• Assess Fe removals (discussed above) as function of nominal HRT = V/Q. • Determine residence time distribution (RTD) and mean HRT from tracer results to assess flow characteristics.	• Plot Fe removal rates as function of HRT to determine design parameters. • Information to be used in the design process, if settling basins are part of the selected remedy.
	Evaluate the effectiveness and required dosing rate of flocculant or coagulant to achieve the desired effluent Fe concentration.	• Jar test results. Determine initial and final turbidity concentrations under a range of chemical doses. • Influent (FDB) TSS and total Fe and effluent (SB1EFF) TSS and total Fe.	• Jar tests will assess Fe removal over a range of different chemical dosages. • Calculate TSS and metals removal rates in SB No.1 as: Removal rate = $Q*(C_{in}-C_{out})$. • Compare influent total Fe concentrations to effluent total Fe concentrations for different operating conditions (i.e., varied chemical dosing).	• Total Fe concentrations are reduced when effluent total Fe is less than influent total Fe. • Best Fe removal in jar tests will be used for initial estimate of chemical dosage in SB No. 1 and will be useful for comparing effects of different chemical doses. • Results to be used during design process to develop operating procedures (i.e., chemical dosing requirements), if settling basins are part of the selected remedy.
	Quantify the rate of sludge accumulation and chemical characteristics of the accumulated sludge.	• Influent (FDB) TSS and total Fe and effluent (SB1EFF) TSS and total Fe Post-demonstration volume estimates of accumulated sludge (depth on bottom of SB. No. 1). • Post-demonstration sludge sampling from 6 locations in SB No. 1 (SB1SL1A through SB1SL6A).	• Sludge analysis results to be compared to sludge disposal criteria. • Mass balance on TSS to be used to estimate sludge production rate. • Mass balance on total metals to be used to estimate accumulation of specific metals in sludge. • Calculate TSS and metals removal rates in SB No.1 as: Removal rate = $Q*(C_{in}-C_{out})$.	• Results to be used during design process to develop operating procedures (i.e., sludge disposal requirements with respect to volume and metals content), if settling basins are part of the selected remedy.

TABLE B-1
TREATABILITY STUDY OBJECTIVES FOR SETTLING BASIN NO. 1
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Remove suspended solids and particulate Fe upstream of the SSF wetland	Identify O&M requirements, including flocculant/coagulant equipment maintenance intervals, accumulated sludge removal requirements, power requirements, and estimated full-scale operational costs.	• Literature review. • Review of manufacturer information • Observations/inspections of system during startup and operation. • Post-test measurement of sludge volume and sludge density. • Capital and O&M costs (including power usage) for demonstration system.	• Calculate sludge mass accumulation rate based on TSS mass balance for SB No.1: Accumulation rate = $Q^*(C_{in}-C_{out})$. • With mass accumulation rate and post-test sludge density, estimate volumetric rate of sludge accumulation. • System observations and modifications to be used to determine routine and potential non-routine maintenance requirements.	• Information to be used for treatment technology evaluation. • If settling basins are selected as part of the final remedy, information to be used during design and for developing operating procedures, maintenance intervals, and sludge removal intervals (utilizing volumetric rate of sludge accumulation), and for estimating O&M costs. • Demonstration system costs to be scaled up to estimate full-scale costs.
	Estimate the amount of heat loss through SB No. 1 and study the effectiveness of insulating balls for heat retention.	• Temperature measurements at influent and effluent ends of SB No. 1. (SB1T01and SB1T02, respectively). • Temperature measurements at influent and effluent ends of SB No. 2 (SB2T01 and SB2T02, respectively).	• Compare influent and effluent water temperatures at SB No. 1 (with HDPE insulating balls). • Compare influent and effluent water temperatures at SB No. 2 (without HDPE insulating balls).	• Effectiveness of HDPE insulating balls to be determined by comparing relative heat loss from SB No. 1 (with HDPE insulating balls) and SB No. 2 (without HDPE insulating balls). HDPE insulating balls will be considered effective if temperature decreases through SB No.1 are less than temperature decreases through SB. No. 2. • Results to be used during design process, if settling basins are part of the selected remedy. Thermal analysis will be incorporated into system design to prevent freezing of settling basins and any subsequent unit processes.

Notes:

1. Objectives for this unit process are described in Section 4.1.2 of the *Constructed Wetland Demonstration Treatability Study Work Plan* (Atlantic Richfield, 2013).
2. Sampling and monitoring locations shown on Figure B-2.
3. Sampling and monitoring program summarized in Table B-2.

Abbreviations:
C_{in} = influent concentration
C_{out} = effluent concentration
Fe = iron
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
gpm = gallons per minute
HDPE = high density polyethylene
HRT = hydraulic residence time
mg/L = milligrams per liter
RTD = residence time distribution
SB No. 1 = Settling Basin No. 1
SSF = subsurface flow
TSS = total suspended solids
Q = flow rate
V = volume

TABLE B-2
FIELD SAMPLING PLAN SUMMARY FOR SETTLING BASIN NO. 1
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Colonization (4 weeks)	SB No. 1	weekly	Field Observations	Routine visual observations / system inspection.
	FDB	weekly	Lab[3]	Evaluate loading to SB No. 1 and treatment performance.
	SB1EFF	weekly	Lab[3]	Evaluate SB No. 1 treatment performance (also influent concentrations to PSFW).
	FM01	continuous	Flow Rate[4]	Monitor flow rate into wetland demonstration for calculating loading rates.
	FDB	continuous	Water Quality[5]	Evaluate influent water quality.
	SB1EFF	continuous	Water Quality[5]	Evaluate changes in water quality (also influent water quality to PSFW).
	SB1T01	continuous	Water Temperature	Monitor water temperature at inlet.
	SB1T02	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
Wetland Demonstration (12 weeks)	SB No. 1	semi-monthly[6]	Field Observations	Routine visual observations / system inspection.
	FDB	semi-monthly[6]	Lab[3]	Evaluate loading to SB No. 1 and treatment performance.
	SB1EFF	semi-monthly[6]	Lab[3]	Evaluate treatment performance and influent concentrations to PSFW.
	FM01	continuous	Flow Rate[4]	Monitor flow rate into wetland demonstration for calculating loading rates.
	FDB	continuous	Water Quality[5]	Evaluate influent water quality.
	SB1EFF	continuous	Water Quality[5]	Evaluate changes in water quality (also influent water quality to PSFW).
	SB1T01	continuous	Water Temperature	Monitor water temperature at inlet.
	SB1T02	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
	SB1EFF	TBD[7]	Rhodamine Tracer Study[7]	Determine hydraulic residence time.
Post-Wetland Demonstration	SB1SL[8]	once	Lab[9]	Characterize sludge to evaluate deposition.

Notes:

1. Location IDs are shown on Figure B-2.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids, and total and dissolved metals using methods shown in Table B-15.
4. Flow rate measurements will be measured using a factory calibrated electromagnetic flowmeter.
5. Field water quality measurements of pH, temperature, SEC, ORP, and DO using continuous methods using methods shown in Table B-15.
6. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.
7. Field measurements of Rhodamine WT tracer dye using in-situ calibrated fluorometer using methods shown in Table B-15. See Table B-16 for tracer study details.
8. Six (6) SB No. 1 sludge (SB1SL) characterization sampling locations are SB1SL1A, SB1SL2A, SB1SL3A, SB1SL4A, SB1SL5A, and SB1SL6A. The number represents transect number (perpendicular to flow) and letter represents a point along the transect.
9. Lab Analyses: acid soluble metals and density using methods shown in Table B-15.

TABLE B-2
FIELD SAMPLING PLAN SUMMARY FOR SETTLING BASIN NO. 1
Rico-Argentine Mine Site
Dolores County, Colorado

Abbreviations:

DO = dissolved oxygen
FDB = concrete flow diversion box
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
ID = identification
ORP = oxidation reduction potential
PSFW = polishing surface flow wetland
SB1EFF = SB No. 1 effluent monitoring location within the Agridrain
SB1T01 = SB No. 1 influent water temperature monitoring location
SB1T02 = SB No. 1 effluent water temperature monitoring location
SB No. 1 = settling basin number 1
SB1SL1A = SB No. 1 sludge sampling location, transect 1, point A
SB1SL2A = SB No. 1 sludge sampling location, transect 2, point A
SB1SL3A = SB No. 1 sludge sampling location, transect 3, point A
SB1SL4A = SB No. 1 sludge sampling location, transect 4, point A
SB1SL5A = SB No. 1 sludge sampling location, transect 5, point A
SB1SL6A = SB No. 1 sludge sampling location, transect 6, point A
SEC = specific electrical conductance
TBD = to be determined

TABLE B-3
TREATABILITY STUDY OBJECTIVES FOR THE POLISHING SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Provide additional pretreatment of suspended solids and particulate Fe	Provide additional pretreatment of suspended solids and particulate Fe	• Influent (SB1EFF) TSS and total Fe and effluent (PSFWEFF) TSS and total Fe.	• Compare influent and effluent TSS and concentrations. • Compare influent and effluent total Fe concentrations. • Determine TSS and total Fe concentration reductions through PSFW.	• Determine TSS and total Fe concentration reductions through PSFW. • Concentrations are acceptably reduced in the PSFW when: o Effluent TSS < influent TSS o Effluent Total Fe < influent total Fe
	Reduce total Fe concentrations from approximately 3 mg/L in the influent to less than 0.5 mg/L in the effluent for flow rates within the range of 10 to 50 gpm.	• Influent (SB1EFF) and effluent (PSFWEFF) total Fe. • Flow rate into SB No. 1 (FM01).	• Compare influent total Fe concentrations to effluent total Fe concentrations.	• Determine reductions in total Fe concentration through PSFW, for the range of tested flow rates. • Total Fe concentrations are acceptably reduced in the PSFW when: o Effluent Total Fe < influent total Fe o For influent (SB1EFF) total Fe of up to 3 mg/L, effluent (PSFWEFF) total Fe is less than 0.5 mg/L
	Evaluate the metals removal associated with precipitation and sedimentation of Fe oxides and hydroxides.	• Influent (SB1EFF) and effluent (PSFWEFF) total Fe and metals concentrations.	• Mass balances on Fe and other metals to be used to evaluate concurrent metals removals. • Calculate metals removal in SB No.1. Metals removal rate to be calculated as: Removal rate = $Q*(C_{in}-C_{out})$	• Information to be used to assess fate of metals in PSFW and for possible design of full-scale unit process.
	Evaluate the surface area required to achieve the desired effluent Fe concentration.	• Influent Fe concentrations (SB1EFF) • Effluent Fe concentrations (PSFWEFF) • Flow rate into PSFW (FM01) • As-built dimensions and wetted surface area of PSFW.	• Fe removal rate (mass per day) to be calculated as $Q*(C_{in}-C_{out})$. • Fe removal rate at each flow rate will be normalized to surface area.	• Area-normalized Fe removal rates will be plotted as function of flow rate to determine design parameters. • Information to be used during design to estimate sizing requirements, if surface flow wetlands are selected as an Fe removal process. • Because the PSFW will not have substantial plant growth, not all of the potential removal mechanisms will be available and active in this system. Thus, any removal through this unit process will be the lower bound on the achievable removal.
	Measure Fe removal rates as compared to the anticipated removal rate of 4 $g/m^2/d$.	• Influent (SB1EFF) and effluent (PSFWEFF) total Fe. • Flow rate into PSFW (FM01).	• Fe removal rate (mass per day) to be calculated as $Q*(C_{in}-C_{out})$ and normalized by dividing by PSFW surface area. • Normalized Fe removal rates will be compared to literature value of 4 $g/m^2/d$.	• Information to be used for treatment technology evaluation. • If surface flow wetlands are selected as an Fe removal process for the final remedy, area-normalized Fe removal rates will be used during design to estimate sizing requirements.
	Quantify the rate of sludge accumulation and its chemical characteristics.	• Influent (SB1EFF) and effluent (PSFWEFF) TSS and total metals concentrations.	• Removal rates will be assumed to be equivalent to sludge mass accumulation rates. • Mass balance to be used to estimate sludge accumulation rate is: Removal rate = $Q*(C_{in}-C_{out})$ • Mass balance on total metals to be used to estimate accumulation of specific metals in sludge.	• Information to be used for treatment technology evaluation. • If selected, information to be used during design and for developing operating procedures.
	Determine the effects of vegetation density and dormancy on Fe removal.	• Influent (SB1EFF) and effluent (PSFWEFF) total Fe. • Flow rate into PSFW (FM01). • Visual observations of vegetation density.	• Fe removal rate (mass per day) to be based on an Fe mass balance and calculated as $Q*(C_{in}-C_{out})$. • Removal rate at a give flow rate to be normalized to surface area. • Normalized removal rates to be compared for different vegetation densities observed during testing.	• Information to be used for treatment technology evaluation. • If selected, information to be used during design to estimate sizing requirements and for developing operating procedures.

TABLE B-3
TREATABILITY STUDY OBJECTIVES FOR THE POLISHING SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Provide additional pretreatment of suspended solids and particulate Fe	Identify O&M requirements, including nutrient requirements, accumulated sludge removal requirements, methods, and estimated full-scale operational costs.	• System observations and inspections • Influent and effluent (SB1EFF and PSFWEFF) concentrations of TSS and total metals; Flow rate into PSFW (FM01). • Literature review and other case studies to assess nutrient requirements and sludge removal methods. • Influent and effluent (SB1EFF and PSFWEFF) concentrations of nitrogen and phosphorus; nutrient content of topsoil. • Capital and O&M costs for demonstration unit.	• Sludge accumulation rates: calculate TSS and total metals accumulation as solids removal rates using $Q^*(C_{in}-C_{out})$; visual inspections to determine sludge removal. • If effluent TSS is greater than influent TSS, previously settled solids are being entrained in flow. • Compare bioavailable nutrient concentrations (water and soil) to plant requirements.	• Capital and O&M costs for demonstration to be used in treatment technology evaluation; costs to be scaled up for estimation of full-scale operating costs. • Information to be used for developing O&M requirements and procedures, sludge removal requirements, and nutrient requirements. • If PSFW selected, information to be used during design and for developing operating procedures.
	Estimate the amount of heat loss through the PSFW.	• Temperature measurements at influent and effluent ends of PSFW (PSFWT01and PSFWT02, respectively).	• Compare influent and effluent water temperatures through the PSFW.	• Results to be used during design process, if PSFW is selected as part of the remedy. Thermal analysis will be incorporated into system design to prevent freezing of the PSFW and any subsequent unit processes.

Notes:
1. Objectives for this unit process are described in Section 4.2.2 of the *Constructed Wetland Demonstration Treatability Study Work Plan* (Atlantic Richfield, 2013).
2. Sampling and monitoring locations shown on Figure B-3.
3. Sampling and monitoring program summarized in Table B-3.

Abbreviations:
< = less than
C_{in} = influent concentration
C_{out} = effluent concentration
Fe = iron
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
$g/m^2/d$. = gram per square meter per day
gpm = gallons per minute
HDPE = high density polyethylene
HRT = hydraulic residence time
mg/L = milligrams per liter
O&M = operations and maintenance
PSFW = polishing surface flow wetland
Q = flow rate
RTD = residence time distribution
SSF = subsurface flow
SB No. 1 = Settling Basin No. 1
TSS = total suspended solids
V = volume

TABLE B-4
FIELD SAMPLING PLAN SUMMARY FOR THE POLISHING SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Colonization (4 weeks)	PSFW	weekly	Field Observations	Routine visual observations / system inspection.
	SB1EFF	weekly	Lab[3,4]	Evaluate loading to PSF wetland; SB1 effluent is PSFW influent.
	PSFWEFF	weekly	Lab[3,4]	Evaluate treatment performance and influent concentrations for SSF wetland.
	SB1EFF	monthly	Lab[5]	Evaluate influent nutrient concentrations for PSFW (SB1 effluent is PSFW influent).
	PSFWEFF	monthly	Lab[5]	Evaluate nutrient use in PSFW and influent nutrient concentrations for SSF wetland.
	SB1EFF	continuous	Water Quality[6]	Evaluate influent water quality.
	PSFWEFF	continuous	Water Quality[6]	Evaluate changes in water quality (also influent water quality to SSF wetland).
	PSFWT01	continuous	Water Temperature	Monitor water temperature at inlet.
	PSFWT02	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
Wetland Demonstration (12 weeks)	PSFW	semi-monthly[7]	Field Observations	Routine visual observations / system inspection.
	SB1EFF	semi-monthly[7]	Lab[3,4]	Evaluate loading to PSFW; SB1 effluent is PSFW influent.
	PSFWEFF	semi-monthly[7]	Lab[3,4]	Evaluate treatment performance and influent concentrations for SSF wetland.
	SB1EFF	monthly	Lab[5]	Evaluate influent nutrient concentrations for PSFW (SB1 effluent is PSFW influent).
	PSFWEFF	monthly	Lab[5]	Evaluate nutrient use in PSFW and influent nutrient concentrations for SSF wetland.
	SB1EFF	continuous	Water Quality[6]	Evaluate influent water quality.
	PSFWEFF	continuous	Water Quality[6]	Evaluate changes in water quality (also influent water quality to SSF wetland).
	PSFWT01	continuous	Water Temperature	Monitor water temperature at inlet.
	PSFWT02	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
	PSFWEFF	TBD	Rhodamine Tracer Study[8]	Determine hydraulic residence time.

Notes:

1. Location IDs are shown on Figure B-3.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids (TSS), and total and dissolved metals using methods shown in Table B-15.
4. Lab Analyses: total organic carbon and biological oxygen demand (BOD) using methods shown in Table B-15. Note that BOD samples have short laboratory holding times (analysis must be completed within 24 hours from the time the sample is collected). Shipment of BOD samples and subsequent BOD analysis within the short holding time may not be possible.
5. Lab Analyses: ammonia nitrogen, nitrate/nitrite nitrogen, and phosphorus using methods shown in Table B-15.

TABLE B-4
FIELD SAMPLING PLAN SUMMARY FOR THE POLISHING SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Notes, continued:

6. Field water quality measurements of pH, temperature, SEC, ORP, and DO using continuous methods using methods shown in Table B-15.
7. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.
8. Field measurements of Rhodamine WT tracer dye using in-situ calibrated fluorometer using methods shown in Table B-15. See Table B-16 for tracer study details.

Abbreviations:
DO = dissolved oxygen
ID = identification
PSFW = polishing surface flow wetland
PSFWEFF = PSFW effluent monitoring location within the Agridrain
PSFWT01 = PSFW influent water temperature monitoring location
PSFWT02 = PSFW effluent water temperature monitoring location
SSF = subsurface flow
SB1EFF = SB No. 1 effluent monitoring location within the Agridrain
TBD = to be determined

TABLE B-5
TREATABILITY STUDY OBJECTIVES FOR THE SUBSURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use

Remove dissolved Cd and Zn from the St. Louis Tunnel discharge.	Remove dissolved Cd and Zn from the St. Louis Tunnel discharge.	• Influent (PSFWEFF) and effluent (SSFWMP011) Cd and Zn concentrations.	• Compare influent and effluent Cd concentrations.
			• Compare influent and effluent Zn concentrations.
			• Determine removals of Cd and Zn concentration reductions through SSFW.
				• Determine Cd and Zn concentration reductions through SSFW.
				• Concentrations are reduced in the SSFW when:
				  o Effluent Cd < influent Cd
				  o Effluent Zn < influent Zn

	Reduce dissolved Cd and Zn concentrations for flow rates within the range of 10 to 50 gpm.	• Influent (PSFWEFF) and effluent (SSFWMP011) Cd and Zn concentrations.
		• Flow rate into SSFW (FM01).
			• Compare influent Cd concentrations to effluent Cd concentrations.
			• Compare influent Zn concentrations to effluent Zn concentrations.
				• Determine Cd and Zn reductions through SSFW, for the range of tested flow rates.
				• Concentrations are acceptably reduced in the SSFW when:
				  o Effluent Cd < influent Cd
				  o Effluent Zn < influent Zn
				• Information to be used during design to estimate sizing requirements, if an SSFW is selected for removal of Cd and Zn.

	Evaluate the metal removal rates and associated HRT required to achieve the desired effluent Cd and Zn concentrations.	• Influent (PSFWEFF) and effluent (SSFWMP011) Cd and Zn concentrations. • Flow rate into SSFW (FM01). • Tracer concentrations as a function of time and resulting residence time distribution from tracer tests.	• Removal rates (mass per day) to be based on mass balances. Removal rates to be calculated as: Removal rate = $Q*(C_{in}-C_{out})$ • Tracer test results to be used to evaluate RTD and mean HRT for SSFW. • Removal rates for Cd and Zn to be calculated at different system flow rates to determine removals as function of HRT. Multiple HRTs will be evaluated by (1) varying the flow rate, and (2) analyzing samples from multiple locations along the flow path (e.g., SFWMP01, SFWMP03, SFWMP06, SFWMP11).	• Information to be used for treatment technology evaluation. • If selected, Cd and Zn removals as function of HRT will be used during design to determine size of an SSFW.
	Determine the effects of matrix composition and SSF wetland design on hydraulic residence time, hydraulic conductivity, and treatment performance over time and identify ways to optimize flow characteristics.	• Matrix composition over time; pre- and post-test matrix samples to be taken at 12 locations • Water levels from routine system monitoring. • Results of tracer tests, slug tests, and permeability tests completed over time. • Results of hydraulic modeling. • Literature search.	• Evaluate changes in matrix composition analyses, hydraulic conductivity, permeability, and HRT over time. • Compare results of demonstration SSFW hydraulic conductivity and permeability tests to results of pilot scale SSFW for comparison of matrix composition effects. • Predict potential flow problems and design modifications to improve flow with modeling. • Evaluate potential modifications using literature information.	• Information to be used for treatment technology evaluation and to determine hydraulic feasibility of full scale SSFW. • If selected, utilize literature, modeling, and field results to inform design of a full-scale SSFW, with the goal of maintaining treatment performance and flow through the system over time.
	Determine the effects of vegetation density on Cd and Zn removal.	• Influent (PSFWEFF) and effluent (SSFWMP011) Cd and Zn concentrations. • Visual observations of vegetation density.	• Compare influent and effluent Cd and Zn concentrations; plot calculated removal rates as a function of vegetation density.	• If selected, Cd and Zn removal as a function of vegetation density will be considered during SSFW design.
	Identify nutrient requirements and consumption/replenishment pathways for the SSF wetland matrix material.	• Literature search of nutrient requirements for SRB and SSFW plants. • Influent (PSFEFF) and effluent (SSFWMP11) nutrient concentrations.	• Compare nutrient analysis of matrix to literature review findings to determine if matrix has sufficient nutrient levels to support SRB and SSFW plants. • Construct mass balance on nutrients to determine fate within system.	• If an SSFW is selected for full scale implementation, nutrient consumption rates will be considered in design and in determining any O&M requirements, specifically for nutrient replenishment.

TABLE B-5
TREATABILITY STUDY OBJECTIVES FOR THE SUBSURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Remove dissolved Cd and Zn from the St. Louis Tunnel discharge.	Estimate metal sulfide, elemental sulfur, and biofilm accumulation rates within the SSF wetland unit process.	• Sulfate, sulfide, total metals, and TSS concentrations at influent (PSFEFF) and effluent (SSFWMP11) locations. • Pre- and post-test matrix sampling at 12 locations.	• Metals and TSS removal rates (mass per day) to be based on mass balances. Removal rates to be calculated as: Removal rate = $Q^*(C_{in}-C_{out})$ • Sulfate and sulfide results to be used to determine fate of sulfur species with the SSFW.	• If an SSFW is selected for full scale implementation, solids accumulation rates will be considered during design to determine O&M requirements for solids removal and to maintain adequate flow through an SSFW.
	Quantify H_2S gas generation sources, rates, and mitigation measures.	• Continuous H_2S monitoring data[4]. • Sulfate and sulfide concentrations at multiple SSFW locations (influent (SSFWMP11) and effluent (ACEFF).	• Mass balances on sulfate and sulfide will be used to determine fate of sulfur species. • H_2S monitoring data will be used to estimate H_2S generation rates and to ensure worker and community safety.	• If a sulfate-reducing unit process is selected as part of the final remedy, monitoring results will be used during design to develop H_2S mitigation methods.
	Identify biofouling sources and mitigation measures.	• Literature search to determine potential methods for biofouling mitigation.	• Evaluate methods cited in literature.	• If a sulfate-reducing unit process is selected as part of the final remedy, biofouling mitigation methods will be considered during design and startup process as part of O&M procedures to maintain flow.
	Identify operation and maintenance requirements, including accumulated metal sulfide, elemental sulfur, and biofilm removal requirements, methods, and estimated full-scale operational costs.	• System observations and inspections. • Analysis of pre- and post-test matrix samples. • Costs for demonstration test. • Literature search to determine potential solids methods.	• Compare TSS and total metals removals under different conditions. • Evaluate methods cited in literature. • Full-scale costs to be estimated by scaling up demonstration operational requirements.	• If selected, information to be used during design to develop O&M procedures (i.e., methods to maintain hydraulic conductivity and/or permeability).
	Estimate the amount of heat loss through the SSF wetland.	• Temperature measurements at influent and effluent ends of SSFW (SSFWMP01 and SSFWMP11, respectively).	• Compare influent and effluent water temperatures at SSFW.	• Results to be used during design process, if SSFW is selected as part of the remedy. Thermal analysis will be incorporated into system design to prevent freezing of the SSFW and any subsequent unit processes.
	Determine the effects of temperature variations on treatment performance.	• Temperature measurements at influent (SSFWMP01) and effluent (SSFWMP11) of SSFW. • Data from 4 temperature profile probes. • Calculated removal rates for Cd and Zn.	• Plot removal rates normalized to hydraulic loading rate as a function of temperature to assess the effects of temperature on treatment performance.	• Information to be used for treatment technology evaluation. • If selected, information to be used during design. Removal rates at low temperatures to be considered when sizing full-scale SSFW.
	Determine if the inlet and outlet structures promote or inhibit uniform flow through the SSF wetland matrix.	• System inspections and visual observations of flow through SSFW. • Water level measurements and hydraulic testing results at monitoring points throughout the SSFW. • Tracer test results (i.e., effluent [ACINF] tracer concentrations as a function of time). • Flow rate into SSFW (FM01).	• Water levels will be used to determine if flows are uniform through SSFW. • Hydraulic conductivity, permeability, and tracer test results (RTD and mean HRT) will be used to determine changes in flow characteristics as the demonstration test progresses.	• If selected, information to be used during design. SSFW components will be modified as necessary with available information to produce uniform flow through a full-scale SSFW.

TABLE B-5
TREATABILITY STUDY OBJECTIVES FOR THE SUBSURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Notes:
1. Objectives for this unit process are described in Section 4.3.2 of the Constructed Wetland Demonstration Treatability Study Work Plan (Atlantic Richfield, 2013)
2. Sampling and monitoring locations shown on Figure B-4.
3. Sampling and monitoring program summarized in Table B-4.
4. H_2S monitoring procedures are described in the H_2S monitoring plan in Section 5 of the Performance Monitoring Plan.

Abbreviations:
< = less than
Cd = cadmium
Cin = influent concentration
Cout = effluent concentration
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
gpm = gallons per minute
H_2S = hydrogen sulfide gas
HRT = hydraulic residence time
O&M = operations and maintenance
Q = flow rate
RTD = residence time distribution
SSF = subsurface flow
SSFW = subsurface flow wetland
TSS = total suspended solids
Zn = zinc

TABLE B-6
FIELD SAMPLING PLAN SUMMARY FOR THE SUBSURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Baseline (1 week)	SSFWM[3]	once	Lab[4,5]	Determine baseline metals and physical properties.
	SSFWMP[6]	once	Total Depth	Determine baseline depth of monitoring ports.
	SSFWMP01	continuous	Water Level and Temperature	Monitor water level and temperature at inlet using a pressure transducer.
	SSFWMP11	continuous	Water Level and Temperature	Monitor water level and temperature at outlet using a pressure transducer.
	SSFWMP[6]	once	Hydraulic Testing[7]	Determine baseline hydraulic conductivity of matrix.
Colonization (4 weeks)	SSF Wetland	weekly	Field Observations	Routine visual observations / system inspection.
	PSFWEFF	weekly	Lab[8,9]	Evaluate loading to SSF wetland.
	SSFWMP06	weekly	Lab[8,9]	Evaluate treatment performance at midpoint of SSF wetland.
	SSFWMP11	weekly	Lab[8,9]	Evaluate treatment performance and influent concentrations for aeration channel.
	SSFWMP[6]	weekly	Water Quality[10], Water Level	Evaluate changes in water quality and system water levels along the length of the wetland.
	PSFWEFF	monthly	Lab[11]	Evaluate influent nutrient concentrations (PSFEFF is SSF wetland influent).
	SSFWMP11	monthly	Lab[11]	Evaluate SSF wetland nutrient usage and influent nutrient concentrations for aeration channel.
	SSFWMP[6]	monthly	Total Depth	Monitor change in water levels and total depth due to particulate accumulation.
	PSFWEFF	continuous	Water Quality[10]	Evaluate influent water quality.
	SSFWMP11	continuous	Water Quality[10]	Evaluate changes in water quality (also influent water quality to aeration channel).
	SSFWMP01	continuous	Water Level and Temperature	Monitor water level and temperature at inlet using a pressure transducer.
	SSFWMP11	continuous	Water Level and Temperature	Monitor water level and temperature at outlet using a pressure transducer.
	SSFTPP[12]	continuous	Matrix Temperature	Monitor temperature gradient through matrix using temperature profile probes.
	SSFWMP[6]	once[7]	Hydraulic Testing[7]	Determine hydraulic conductivity of matrix before wetland demonstration testing.
	SSFWMP[6]/ACINF	TBD	NaBr or LiCl Tracer Study[13]	Determine hydraulic residence time and residence time distribution.

TABLE B-6
FIELD SAMPLING PLAN SUMMARY FOR THE SUBSURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Wetland Demonstration (12 weeks)	SSFW	semi-monthly[14]	Field Observations	Routine visual observations / system inspection.
	PSFWEFF	semi-monthly[14]	Lab[8,9]	Evaluate loading to SSF wetland.
	SSFWMP06	semi-monthly[14]	Lab[8,9]	Evaluate treatment performance at midpoint of SSF wetland.
	SSFWMP11	semi-monthly[14]	Lab[8,9]	Evaluate treatment performance and influent concentrations for aeration channel.
	SSFWMP01	semi-monthly[14]	Water Quality[10], Water Level	Evaluate changes in water quality and system water levels along the length of the wetland.
	SSFWMP06	semi-monthly[14]	Water Quality[10], Water Level	Evaluate changes in water quality and system water levels along the length of the wetland.
	SSFWMP09	semi-monthly[14]	Water Quality[10], Water Level	Evaluate changes in water quality and system water levels along the length of the wetland.
	PSFWEFF	monthly	Lab[11]	Evaluate influent nutrient concentrations (PSFEFF is SSF wetland influent).
	SSFWMP11	monthly	Lab[11]	Evaluate SSF wetland nutrient usage and influent nutrient concentrations for aeration channel.
	SSFWMP[6]	monthly	Total Depth	Monitor change in water levels and total depth due to particulate accumulation.
	PSFWEFF	continuous	Water Quality[10]	Evaluate influent water quality.
	SSFWMP11	continuous	Water Quality[10]	Evaluate changes in water quality (also influent water quality to aeration channel).
	SSFWMP01	continuous	Water Level, Temperature	Monitor water level and temperature at inlet using a pressure transducer.
	SSFWMP11	continuous	Water Level, Temperature	Monitor water level and temperature at inlet using a pressure transducer.
	SSFTPP[12]	continuous	Matrix Temperature	Monitor temperature gradient through matrix using temperature profile probes.
	SSFWMP[6]	once[8]	Hydraulic Testing[7]	Determine hydraulic conductivity of matrix at the end of wetland demonstration testing.
	SSFWMP[6]/ACINF	TBD	NaBr or LiCl Tracer Study[13]	Determine hydraulic residence time and residence time distribution.
Post-Wetland Demonstration	SSFWM[3]	once	Lab[4]	Characterize accumulated metal concentrations in matrix material.
	SSFWM[3]	once	Lab[5]	Determine final physical properties of matrix.

TABLE B-6
FIELD SAMPLING PLAN SUMMARY FOR THE SUBSURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Notes:

1. Location IDs are shown on Figure B-4.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Twelve (12) SSF wetland matrix (SSFWM) sampling locations are SSFWM1A, SSFWM1B, SSFWM1C, SSFWM1D, SSFWM2A, SSFWM2B, SSFWM2C, SSFWM2D, SSFWM3A, SSFWM3B, SSFWM3C, and SSFWM3D. The number represents transect number (perpendicular to flow) and letter represents a point along the transect.
4. Lab Analysis: acid soluble metals using methods shown in Table B-15.
5. Lab Analyses: porosity and permeability using methods shown in Table B-15.
6. Eleven (11) SSF wetland monitoring ports are SSFWMP01, SSFWMP02, SSFWMP03, SSFWMP04, SSFWMP05, SSFWMP06, SSFWMP07, SSFWMP08, SSFWMP09, SSFWMP10, and SSFWMP11.
7. Perform at least three slug tests per SSF wetland monitoring port.
8. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids (TSS), and total and dissolved metals using methods shown in Table B-15.
9. Lab Analyses: total organic carbon (TOC) and biological oxygen demand (BOD) using methods shown in Table B-15.
10. Field water quality measurements of pH, temperature, SEC, ORP, and DO using direct or continuous methods using methods shown in Table B-15.
11. Lab Analyses: ammonia nitrogen, nitrate/nitrite nitrogen, and phosphorus using methods shown in Table B-15.
12. Four (4) SSF wetland temperature profile probes are SSFWTPP01, SSFWTPP02, SSFWTPP03, and SFFWTPP04.
13. Field measurements of NaBr or LiCl using ion-specific electrode using methods shown in Table B-15. Samples will be collected hourly using an automatic sampler. See Table B-16 for tracer study details.
14. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.

Abbreviations:

ACINF = aeration channel influent monitoring location within the Agridrain
DO = dissolved oxygen
ID = identification
LiCl - lithium chloride
NA = not applicable
NaBr = sodium bromide
ORP = oxidation reduction potential
PSFW = polishing surface flow wetland
PSFWEFF = PSFW effluent monitoring location within the Agridrain
SEC = specific electrical conductance
SSF = subsurface flow
SSFWMP = SSF wetland monitoring port
SSFWM1A = SSF wetland matrix sampling location, transect 1, point A
SSFWM1B = SSF wetland matrix sampling location, transect 1, point B
SSFWM1C = SSF wetland matrix sampling location, transect 1, point C
SSFWM1D = SSF wetland matrix sampling location, transect 1, point D
SSFWM2A = SSF wetland matrix sampling location, transect 2, point A
SSFWM2B = SSF wetland matrix sampling location, transect 2, point B
SSFWM2C = SSF wetland matrix sampling location, transect 2, point C
SSFWM2D = SSF wetland matrix sampling location, transect 2, point D
SSFWM3A = SSF wetland matrix sampling location, transect 3, point A
SSFWM3B = SSF wetland matrix sampling location, transect 3, point B
SSFWM3C = SSF wetland matrix sampling location, transect 3, point C
SSFWM3D = SSF wetland matrix sampling location, transect 3, point D
SSFWTPP01 = SSF wetland temperature profile probe No. 1
SSFWTPP02 = SSF wetland temperature profile probe No. 2
SSFWTPP03 = SSF wetland temperature profile probe No. 3
SSFWTPP04 = SSF wetland temperature profile probe No. 4
SSFWMP01 = SSF wetland monitoring port number 1
SSFWMP02 = SSF wetland monitoring port number 2
SSFWMP03 = SSF wetland monitoring port number 3
SSFWMP04 = SSF wetland monitoring port number 4
SSFWMP05 = SSF wetland monitoring port number 5
SSFWMP06 = SSF wetland monitoring port number 6
SSFWMP07 = SSF wetland monitoring port number 7
SSFWMP08 = SSF wetland monitoring port number 8
SSFWMP09 = SSF wetland monitoring port number 9
SSFWMP10 = SSF wetland monitoring port number 10
SSFWMP11 = SSF wetland monitoring port number 11
TBD = to be determined

TABLE B-7
TREATABILITY STUDY OBJECTIVES FOR THE AERATION CHANNEL
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Re-aerate the anaerobic SSF wetland effluent, promote settling of precipitated elemental sulfur, and remove biomass prior to flow entering the aerobic rock drain.	Re-aerate the anaerobic SSF wetland effluent, promote settling of precipitated elemental sulfur, and remove biomass prior to flow entering the aerobic rock drain.	• Dissolved oxygen (DO) concentrations along length of aeration channel (influent is SSFWMP11; midpoint is ACMID; effluent is ACEFF). • TSS, sulfate, and sulfide concentrations along length of aeration channel. • Visual observations of sediment accumulation. • Post-test sampling and analysis of sediment that accumulates on and among rocks (post-test sampling locations ACM1A - ACM6A).	• Monitor DO concentrations along the length of the aeration channel to determine the rate at which reaeration occurs. • Visual observations of sediment accumulation over time through the aeration channel. • Settling of elemental sulfur and biomass is promoted if solids concentrations (TSS, VSS, total metals) decrease from the influent (SSFWMP11) to effluent (ACEFF).	• If selected as part of the final remedy, reaeration and solids removal data will be used during design to estimate sizing requirements and for developing operating procedures.
	Demonstrate that an aeration channel can effectively increase dissolved oxygen concentrations for flow rates within the range of 10 to 50 gpm.	• DO concentrations along the length of the aeration channel (influent is SSFWMP11; midpoint is ACMID; effluent is ACEFF). • Flow rate (FM01).	• Monitor and compare DO concentrations along the length of the aeration channel.	• Anaerobic SSF effluent is reaerated if DO concentrations increase along the length of the aeration channel, for a range of flow rates tested. • If selected as part of the final remedy, reaeration data will be used during design to estimate sizing requirements and for developing operating procedures.
	Evaluate the depth, width, length, and slope required to achieve the desired precipitation, settling, and aeration.	• Total and dissolved metals, DO, and TSS concentrations along the length of the aeration channel (influent is SSFWMP11; midpoint is ACMID; effluent is ACEFF).	• To evaluate precipitation and settling of metals, compare total and dissolved metals concentrations along the length of the aeration channel. Decreases in dissolved metals may indicate precipitation; decrease in total metals may indicate settling or other removal of precipitated metals. • To evaluate reaeration, compare DO concentrations along the length of the aeration channel.	• If selected as part of the final remedy, reaeration data will be used during design to determine aeration channel length needed for sufficient reaeration and solids removal.
	Quantify H_2S gas generation sources, rates, and mitigation methods.	• Continuous H_2S monitoring data[4] • Sulfate and sulfide concentrations at aeration channel influent (SSFWMP11) and effluent (ACEFF).	• Mass balances on sulfate and sulfide will be used to determine fate of sulfur species. • H_2S monitoring data will be used to estimate H_2S generation rates and to ensure worker and community safety. • H_2S monitoring data will be used to evaluate if engineered media installed inside of the aeration channel inlet structure reduces H_2S emissions.	• If a sulfate-reducing unit process is selected as part of the final remedy, monitoring results will be used during design to develop H_2S mitigation methods.
	Quantify elemental sulfur and biomass accumulation and chemically characterize these materials.	• TSS and metals data along the length of the aeration channel. • Post-test analysis (biomass and metals) of matrix samples along length of aeration channel (ACM1A through ACM6A).	• Utilize solids, sulfur, and metals data to estimate removal along the length of the channel. • Utilize post-test matrix data to determine removals throughout the test.	• If selected as part of the final remedy, data will be used during design to estimate accumulation rates and estimate removal intervals. Information will also be used to develop maintenance procedures.
Re-aerate the anaerobic SSF	Evaluate the extent to which metal sulfides may be re-oxygenated and dissolved.	• Dissolved metals concentrations along the length of the aeration channel.	• Oxidation of metal sulfides will increase dissolved metals concentrations. Increases in concentrations of dissolved metals (particularly Cd and Zn) will indicate dissolution of metal sulfides.	• If selected as part of the final remedy, information will be used to develop design modifications to prevent oxidation of metal sulfides and release of elevated metals concentrations, if necessary.

TABLE B-7
TREATABILITY STUDY OBJECTIVES FOR THE AERATION CHANNEL
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
wetland effluent, promote settling of precipitated elemental sulfur, and remove biomass prior to flow entering the aerobic rock drain.	Identify O&M requirements, including accumulated sulfur and biofilm removal requirements, methods, and estimated full-scale operational costs.	• System observations and inspections. • Analysis of pre- and post-test matrix samples. • Costs for demonstration test • Literature search to determine potential solids methods.	• Compare TSS and total metals removals under different conditions. • Evaluate methods cited in literature. • Full-scale costs to be estimated by scaling up demonstration operational requirements.	• Information to be used for treatment technology evaluation. • If selected as part of the final remedy, information will be used during design to determine sufficient aeration channel size, to develop O&M procedures (including timing and methods for removal of accumulated solids), and for estimating full-scale operating costs.
	Estimate the amount of heat loss through the aeration channel.	• Temperature measurements along length of aeration channel (influent is SSFWMP11; midpoint is ACMID; effluent is ACEFF).	• Compare influent and effluent water temperatures through aeration channel.	• Results to be used during design process, if aeration channel is selected as part of the final remedy. Thermal analysis will be incorporated into system design to prevent freezing of the aeration channel and any subsequent unit processes.

Notes:
1. Objectives for this unit process are described in Section 4.4.2 of the *Constructed Wetland Demonstration Treatability Study Work Plan* (Atlantic Richfield, 2013).
2. Sampling and monitoring locations shown on Figure B-5.
3. Sampling and monitoring program summarized in Table B-5.
4. H_2S monitoring procedures are described in the H_2S monitoring plan in Section 5 of the Performance Monitoring Plan.

Abbreviations:
< = less than
Cd = cadmium
Cin = influent concentration
Cout = effluent concentration
DO = dissolved oxygen
Fe = iron
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
gpm = gallons per minute
H_2S = hydrogen sulfide gas
HRT = hydraulic residence time
mg/L = milligrams per liter
O&M = operations and maintenance
PSFW = polishing surface flow wetland
Q = flow rate
RTD = residence time distribution
SSF = subsurface flow
TSS = total suspended solids
V = volume
Zn = zinc

TABLE B-8
FIELD SAMPLING PLAN SUMMARY FOR THE AERATION CHANNEL
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Colonization (4 weeks)	Aeration Channel	weekly	Field Observations	Routine visual observations / system inspection.
	SSFWMP11	weekly	Lab[3,4]	Evaluate loading to aeration channel.
	ACEFF	weekly	Lab[3,4]	Evaluate treatment performance (also influent concentrations for rock drain).
	ACMID	weekly	Water Quality[5]	Evaluate changes in water quality at midpoint.
	SSFWMP11	monthly	Lab[6]	Evaluate influent nutrient concentrations (SSFWMP11 is aeration channel influent).
	ACEFF	monthly	Lab[6]	Evaluate aeration channel nutrient usage and influent nutrient concentrations for rock drain.
	SSFWMP11	continuous	Water Quality[5]	Evaluate influent water quality.
	ACEFF	continuous	Water Quality[5]	Evaluate changes in water quality (also influent water quality to rock drain).
Wetland Demonstration (12 weeks)	Aeration Channel	semi-monthly[7]	Field Observations	Routine visual observations / system inspection.
	SSFWMP11	semi-monthly[7]	Lab[3,4]	Evaluate loading to aeration channel.
	ACEFF	semi-monthly[7]	Lab[3,4]	Evaluate treatment performance and influent concentrations for rock drain.
	ACMID	semi-monthly[7]	Water Quality[5]	Evaluate changes in water quality at midpoint.
	SSFWMP11	monthly	Lab[6]	Evaluate influent nutrient concentrations (SSFWMP11 is aeration channel influent).
	ACEFF	monthly	Lab[6]	Evaluate aeration channel nutrient usage and influent nutrient concentrations for rock drain.
	SSFWMP11	continuous	Water Quality[5]	Evaluate influent water quality.
	ACEFF	continuous	Water Quality[5]	Evaluate changes in water quality (also influent water quality to rock drain).
	ACINF	TBD	Rhodamine Tracer Study[8]	Determine hydraulic residence time.
Post-Wetland Demonstration	ACM[9]	once	Lab[10]	Characterize metal concentrations in accumulated sediment.

Notes:
1. Location IDs are shown on Figure B-5.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids, and total and dissolved metals using methods shown in Table B-15.
4. Lab Analyses: total organic carbon (TOC) and biological oxygen demand (BOD) using methods shown in Table B-15.
5. Field water quality measurements of pH, temperature, SEC, ORP, and DO using direct or continuous methods using methods shown in Table B-15.
6. Lab Analyses: ammonia nitrogen, nitrate/nitrite nitrogen, and phosphorus using methods shown in Table B-15.
7. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.
8. Field measurements of Rhodamine WT tracer dye using in-situ calibrated fluorometer using methods shown in Table B-15. See Table B-16 for tracer study details.
9. Six (6) aeration channel matrix (ACM) characterization sampling locations are ACM1A, ACM2A, ACM3A, ACM4A, ACM5A, and ACM6A. The number represents transect number (perpendicular to flow) and letter represents a point along the transect.
10. Lab Analysis: acid soluble metals using methods shown in Table B-15.

TABLE B-8
FIELD SAMPLING PLAN SUMMARY FOR THE AERATION CHANNEL
Rico-Argentine Mine Site
Dolores County, Colorado

Abbreviations:

ACEFF = aeration channel effluent monitoring location within the outlet control box
ACINF = aeration channel influent monitoring location within the Agridrain water level control structure
ACM = aeration channel matrix
ACM1A = ACM characterization sampling location, transect 1, point A
ACM1B = ACM characterization sampling location, transect 1, point B
ACM2A = ACM characterization sampling location, transect 2, point A
ACM2B = ACM characterization sampling location, transect 2, point B
ACM3A = ACM characterization sampling location, transect 3, point A
ACM3B = ACM characterization sampling location, transect 3, point B
ACMID = aeration channel midpoint monitoring location.
DO = dissolved oxygen
FDB = concrete flow diversion box
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
ID = identification
NA = not applicable
ORP = oxidation reduction potential
SEC = specific electrical conductance
TBD = to be determined

TABLE B-9
TREATABILITY STUDY OBJECTIVES FOR THE ROCK DRAIN
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Reduce the concentration of dissolved Mn.	Primary treatment objective: reduce the concentration of dissolved Mn.	• Influent (ACEFF) and effluent (RDEFF) Mn concentrations.	• Compare effluent Mn to influent Mn • Calculate Mn removal rate as: Removal rate = $Q*(C_{in}-C_{out})$	• Information to be used for treatment technology evaluation. • If rock drain effectively reduces dissolved Mn concentrations and is selected as part of final remedy, demonstration results will be used for designing full scale rock drain.
	Reduce dissolved Mn concentrations for flow rates within the range of 10 to 50 gpm at water temperatures as low as 6°C.	• Influent (ACEFF) and effluent (RDEFF) Mn concentrations. • Flow rate (FM01 or FM04).	• Compare effluent Mn to influent Mn • Calculate Mn removal rate as: Removal rate = $Q*(C_{in}-C_{out})$	• Information to be used for treatment technology evaluation. • If rock drain effectively reduces dissolved Mn concentrations for a range of flow rates and is selected as part of final remedy, demonstration results will be used for designing full scale rock drain.
	Evaluate the Mn removal rate and associated HRT required to achieve desired effluent Mn concentrations.	• Dissolved Mn concentrations at the rock drain influent (ACEFF), effluent (RDEFF), and intermediate sampling location (RDMP04). • Flow rate (FM01 or FM04). • Tracer test results.	• Tracer test to be used to evaluate RTD and mean HRT for entire rock drain and for intermediate sampling locations (RDMP01 through RDMP06). • Calculate Mn removal rates as: Removal rate = $Q*(C_{in}-C_{out})$ • Plot Mn removal rates as a function of HRT to evaluate best operating conditions.	• Operation of rock drain at a given HRT is acceptable if effluent dissolved Mn (RDEFF) is below the target effluent Mn concentration. • If a rock drain is selected as part of the final remedy, removal of dissolved Mn as a function of HRT will be considered during design and development of operating procedures.
	Quantify MnO_2 accumulation rates.	• Dissolved Mn concentrations at the rock drain influent (ACEFF), effluent (RDEFF), and intermediate sampling location (RDMP04). • Baseline and post-test analysis of metals on rock drain media surfaces; samples from 6 locations along rock drain.	• Assuming that MnO_2 accumulation corresponds to decreases in total Mn, calculate MnO_2 accumulation rates based on changes total Mn from influent to effluent: Mn Removal rate = $Q*(C_{in}-C_{out})$ • Baseline and post-test analysis of Mn on rock drain media surfaces will be direct indicator of Mn accumulation.	• If selected, information to be used during design process for developing operating procedures for solids removal and for cost estimates for full-scale system.
	Identify biofouling sources and mitigation methods.	• Literature search of maintenance methods that have been used elsewhere to mitigate biofouling in trickling filters and similar Mn-oxidizing reactors.	• Evaluate methods cited in literature.	• If a Mn-oxidizing rock drain is selected as part of the final remedy, biofouling mitigation methods will be considered during design and startup process as part of O&M procedures to maintain flow.
	Identify operation and maintenance requirements, including accumulated MnO_2 removal requirements, methods, and estimated full-scale operational costs.	• System observations and inspections. • Analysis of pre- and post-test matrix samples. • Costs for demonstration test • Literature search to determine potential solids methods.	• Compare TSS and Mn removals under different conditions. • Evaluate methods cited in literature. • Full-scale costs to be estimated by scaling up demonstration operational requirements.	• If selected, information to be used during design to develop O&M procedures (i.e., methods to maintain hydraulic conductivity and/or permeability).
	Estimate the amount of heat loss through the rock drain.	• Temperature measurements at influent (RDMP01) and effluent (RDMP06) ends of RD.	• Compare influent and effluent water temperatures at the rock drain.	• Results to be used during design process, if a rock drain is selected as part of the remedy. Thermal analysis will be incorporated into system design to prevent freezing of the rock drain and any subsequent unit processes.

TABLE B-9
TREATABILITY STUDY OBJECTIVES FOR THE ROCK DRAIN
Rico-Argentine Mine Site
Dolores County, Colorado

Treatment Objective(s)	Specific Objectives[1] (stated in Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Reduce the concentration of dissolved Mn.	Determine the effects of temperature variations on treatment performance.	• Temperature measurements at influent (RDMP01) and effluent (RDMP06) ends of RD • Dissolved Mn concentrations at the rock drain influent (ACEFF), effluent (RDEFF), and intermediate sampling location (RDMP04). • Flow rate (FM01 or FM04).	• Calculate Mn removal rates as: Removal rate = $Q^*(C_{in}-C_{out})$ • Normalize Mn removal rates to hydraulic loading. • Plot normalized Mn removal rates as a function of water temperature to evaluate temperature effects.	• Information to be used for treatment technology evaluation (i.e., rock drain performance under likely low temperature operation). • If selected, information to be used during design process. Estimated Mn removal at minimum likely operating temperature will be used for sizing of full-scale rock.
	Compare size, shape, and type of wetland demonstration rocks to pilot scale rocks with respect to effects on hydraulic residence time, hydraulic conductivity, and treatment performance over time.	• Tracer test results (i.e., effluent [RDEFF] tracer concentrations as a function of time). • Literature search.	• Evaluate changes in RTD, mean HRT, and hydraulic conductivity with field and laboratory results for both the wetland demonstration and pilot-scale wetland. • Evaluate potential modifications using literature information. • Predict potential flow problems and design modifications to improve flow with modeling.	• If selected, utilize literature, modeling, and field results to inform design of a full-scale rock drain, with the goal of maintaining treatment performance and flow through the system over time.

Notes:
1. Objectives for this unit process are described in Section 4.5.2 of the Constructed Wetland Demonstration Treatability Study Work Plan (Atlantic Richfield, 2013).
2. Sampling and monitoring locations shown on Figure B-5.
3. Sampling and monitoring program summarized in Table B-6.

Abbreviations:
Cin = influent concentration
Cout = effluent concentration
FM01 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 1
FM04 = flowmeter inline with the rock drain effluent piping to Pond 18
gpm = gallons per minute
HRT = hydraulic residence time
mg/L = milligrams per liter
Mn = manganese
MnO2 = manganese dioxide
O&M = operations and maintenance
RD = rock drain
RTD = residence time distribution
TSS = total suspended solids

TABLE B-10
FIELD SAMPLING PLAN SUMMARY FOR THE ROCK DRAIN

Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Baseline (1 week)	RDM[3]	once	Lab[4]	Determine baseline metals on rock.
	RDMP[5]	once	Total Depth	Determine baseline depth of monitoring ports after construction.
Colonization (4 weeks)	Rock Drain	weekly	Field Observations	Routine visual observations / system inspection.
	ACEFF	weekly	Lab[6,7]	Evaluate loading to rock drain.
	RDMP04	weekly	Lab[6,7]	Evaluate treatment performance at midpoint of rock drain.
	RDEFF	weekly	Lab[6,7]	Evaluate treatment performance and effluent concentrations from system.
	RDMP[5]	weekly	Water Quality[8], Water Level	Evaluate changes in water quality and system water levels during colonization.
	RDMP01	continuous	Water Temperature	Monitor water temperature at inlet.
	RDMP06	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
	ACEFF	monthly	Lab[9]	Evaluate influent nutrient concentrations.
	RDEFF	monthly	Lab[9]	Evaluate effluent nutrient concentrations.
	RDEFF	monthly	Lab[10]	Monitor effluent quality from rock drain into Pond 18.
	RDMP[5]	monthly	Total Depth	Monitor change in water levels and total depth.
	RDEFF	continuous	Water Quality[8]	Monitor changes in process chemistry.
	RDTPP[11]	continuous	Matrix Temperature	Monitor temperature gradient through matrix.
	FM04	continuous	Flow Rate	Monitor effluent flow rate from wetland demonstration.
Wetland Demonstration (12 weeks)	Rock Drain	semi-monthly[12]	Field Observations	Routine visual observations / system inspection.
	ACEFF	semi-monthly[12]	Lab[6,7]	Evaluate loading to rock drain.
	RDMP04	semi-monthly[12]	Lab[6,7]	Evaluate treatment performance at midpoint of rock drain.
	RDEFF	semi-monthly[12]	Lab[6,7]	Evaluate treatment performance and influent concentrations for aeration channel.
	RDMP[5]	semi-monthly[12]	Water Quality[8], Water Level	Evaluate changes in water quality and system water levels during tests.
	RDMP01	continuous	Water Level and Temperature	Monitor water temperature at inlet.
	RDMP06	continuous	Water Level and Temperature	Monitor water temperature at outlet to evaluate heat loss.
	ACEFF	monthly	Lab[9]	Evaluate influent nutrient concentrations.
	RDEFF	monthly	Lab[9,10]	Monitor effluent quality and nutrient concentrations from rock drain into Pond 18.
	RDMP[5]	monthly	Total Depth	Monitor change in water levels and total depth.
	RDEFF	continuous	Water Quality[8]	Monitor changes in process chemistry.
	RDTPP[11]	continuous	Matrix Temperature	Monitor temperature gradient through matrix.
	FM04	continuous	Flow Rate	Monitor effluent flow rate from wetland demonstration.
	RDMP[5]/RDEFF	TBD	Tracer Study[13]	Determine hydraulic residence time and residence time distribution.
Post-Wetland Demonstration	RDM[5]	once	Lab[4]	Characterize accumulated metal concentrations in rock drain matrix.

TABLE B-10
FIELD SAMPLING PLAN SUMMARY FOR THE ROCK DRAIN
Rico-Argentine Mine Site
Dolores County, Colorado

Notes:

1. Location ID are shown on Figure B-5.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Rock drain matrix (RDM) characterization sampling locations are RDM1A, RDM1B, RDM2A, RDM2B, RDM3A,and RDM3B.
   The number represents transect number (perpendicular to flow) and letter represents a point along the transect.
4. Lab Analysis: acid soluble metals using methods shown in Table B-15.
5. Six (6) rock drain monitoring ports are RDMP01, RDMP02, RDMP03, RDMP04, RDMP05, and RDMP06.
6. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids, and total and dissolved metals using methods shown in Table B-15.
7. Lab Analyses: total organic carbon (TOC) and biological oxygen demand (BOD) using methods shown in Table B-15.
8. Field water quality measurements of pH, temperature, SEC, ORP, and DO using direct or continuous methods using methods shown in Table B-15.
9. Lab Analyses: ammonia nitrogen, nitrate/nitrite nitrogen, and phosphorus using methods shown in Table B-15.
10. Lab Analyses: Total and Dissolved Metals: Sb, Ba, Be, Cr, Mg, K, Si, Se, Ag, Na, Tl, V; total chloride, total cyanide, total sulfide, and TOC using methods shown in Table B-15.
11. Two (2) rock drain temperature profile probes are RDTPP01 and RDTPP02.
12. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.
13. Field measurements of Rhodamine WT tracer dye using in-situ calibrated fluorometer using methods shown in Table B-15. See Table B-16 for tracer study details.

Abbreviations:

ACEFF = aeration channel effluent monitoring location located with outlet control box
DO = dissolved oxygen
FM04 = flowmeter inline with the piping from Agridrain to Pond 18
ID = identification
ORP = oxidation reduction potential
RDEFF = rock drain effluent monitoring location within the Agridrain
RDM = rock drain matrix
RDMP = rock drain monitoring port
RDMP01 = rock drain monitoring port number 1
RDMP02 = rock drain monitoring port number 2
RDMP03 = rock drain monitoring port number 3
RDMP04 = rock drain monitoring port number 4
RDMP05 = rock drain monitoring port number 5
RDMP06 = rock drain monitoring port number 6
RDM1A = rock drain matrix characterization sampling location, transect 1, point A
RDM1B = rock drain matrix characterization sampling location, transect 1, point B
RDM2A = rock drain matrix characterization sampling location, transect 2, point A
RDM2B = rock drain matrix characterization sampling location, transect 2, point B
RDM3A = rock drain matrix characterization sampling location, transect 3, point A
RDM3B = rock drain matrix characterization sampling location, transect 3, point B
RDTPP01 = rock drain temperature profile probe No. 1
RDTPP02 =rock drain temperature profile probe No. 2
SEC = specific electrical conductance
TBD = to be determined

TABLE B-11
TREATABILITY STUDY OBJECTIVES FOR SETTLING BASIN NO. 2
Rico-Argentine Mine Site
Dolores County, Colorado

Primary Objective(s)	Specific Objectives[1] (from Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Usage
Evaluate Gunderboom® treatment mechanisms for removal of suspended solids and particulate Fe.	Evaluate the removal of suspended solids and particulate Fe using a water permeable Gunderboom® absorptive curtain.	• Influent (FDB) and effluent (SB2EFF) TSS and Fe • Flow rate (FM02)	• Calculate removal rates under different conditions as: Removal rate = $Q^*(C_{in}-C_{out})$	• If a settling basin equipped with a water permeable Gunderboom® absorptive curtain is selected as part of final remedy, removal rates under different conditions will be used during design.
	Reduce total Fe concentrations from as high as 12 mg/L in the influent to approximately 3 mg/L in the effluent.	• Influent (FDB) and effluent (SB2EFF) total Fe • Flow rate (FM02)	• Compare influent total Fe concentrations to effluent total Fe concentrations, over a range of test conditions	• Total Fe concentrations are reduced when effluent total Fe is less than influent total Fe. • For influent (FDB) total Fe of up to 12 mg/L, effluent (SB1EFF) total Fe is less than 3 mg/L • If a settling basin is selected as part of final remedy, Fe removal rates under different conditions will be used for design and to select operating conditions.
	Quantify the rate of sludge accumulation and the chemical characteristics of accumulated sludge.	• Influent and effluent TSS data (FDB and SB2EFF, respectively) • Post-demonstration volume estimates of accumulated sludge (depth on bottom of SB. No. 2) • Post-demonstration sludge sampling from 6 locations in SB No. 2 (SB2SL1A through SB2SL6A)	• Mass balances on TSS and total metals concentrations can be used to determine removal rates, which are equivalent to sludge accumulation rates. Removal rates to be calculated as: Removal rate = $Q^*(C_{in}-C_{out})$ • Metals removal rates will be used to estimate metals composition of accumulated sludge. • Sludge analysis will verify metals composition of accumulated sludge.	• If selected as part of remedy, sludge accumulation rates will be used to estimate O&M requirements for a settling basin, and metals composition of sludge will be used to evaluate sludge disposal requirements.
	Estimate the amount of heat loss through SB No. 2 and study the effectiveness of insulating balls for heat retention.	• Temperature measurements at influent and effluent ends of SB No. 2 (SB2T01and SB2T02, respectively).	• Heat loss is related to temperature decrease from influent to effluent. • Heat loss evaluation in SB No. 2 will compare influent and effluent water temperatures at SB No. 2.	• Information will be used in the design process for developing methods to prevent freezing of settling basins and downstream unit processes.
	Observe inlet and outlet flow patterns and velocities to determine if the inlet and outlet structures promote or inhibit Fe removal.	• System inspections and visual observations of SB No. 2. • Flow rate into SB No. 2 (FM02). • Tracer test results (i.e., effluent [SB2EFF] tracer concentrations as a function of time). • As-built dimensions of SB No. 2.	• Tracer test to be used to evaluate RTD of SB No. 2. RTD will indicate if non-ideal flow caused by inlet and/or outlet structures (e.g., short circuiting) occurs in SB No. 2.	• If a settling basin is selected as part of the final remedy, flow patterns through SB No. 2 will be considered during system design.
	Evaluate the effectiveness, capital and operating costs, and operation and maintenance requirements, including equipment maintenance intervals and accumulated sludge removal requirements, for various Fe removal technologies that may be employed for a full-scale system.	• Calculated TSS and total Fe removal rates and sludge accumulation rates. • Literature review of sludge removal methods from similar settling basins. • Pre- and post-test system inspections and visual observations of SB No.2. • Capital and O&M costs for demonstration SB No.2.	• Compare TSS and total metals removals under different conditions. • System observations to be used to develop O&M requirements for settling basins. • Full-scale costs to be estimated by scaling up demonstration operational requirements.	• Information to be used for treatment technology evaluation. • If selected, information to be used during design process, for developing operating procedures, and for cost estimates for full-scale system.

TABLE B-11
TREATABILITY STUDY OBJECTIVES FOR SETTLING BASIN NO. 2
Rico-Argentine Mine Site
Dolores County, Colorado

Notes:

1. Objectives for this unit process are described in Section 4.6.2 of the Constructed Wetland Demonstration Treatability Study Work Plan (Atlantic Richfield, 2013).
2. Sampling and monitoring locations shown on Figure B-2.
3. Sampling and monitoring program summarized in Table B-6.

Abbreviations:

Cin = influent concentration
Cout = effluent concentration
Fe = iron
FM02 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 2
gpm = gallons per minute
HDPE = high density polyethylene
HRT = hydraulic residence time
mg/L = milligrams per liter
O&M = operations and maintenance
Q = flow rate
RTD = residence time distribution (RTD
SB No. 1 = Settling Basin No. 1
SB No. 2 = Settling basin No. 2
TSS = total suspended solids
SSF = subsurface flow
V = volume

TABLE B-12
FIELD SAMPLING PLAN SUMMARY FOR SETTLING BASIN NO. 2
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Wetland Demonstration (12 weeks)	SB No. 2	semi-monthly[3]	Field Observations	Routine visual observations / system inspection.
	FDB	semi-monthly[3]	Lab[4]	Evaluate loading to SB No. 2 and treatment performance.
	SB2EFF	semi-monthly[3]	Lab[4], Water Quality[5]	Evaluate treatment performance and evaluate effluent water quality.
	SB2EFF	monthly	Lab[6]	Monitor effluent quality from SB No. 2 into Pond 18.
	FM02	continuous	Flow Rate[7]	Monitor flow rate into SB No. 2 for calculating loading rates.
	FDB	continuous	Water Quality[5]	Evaluate influent water quality.
	SB2T01	continuous	Water Temperature	Monitor water temperature at inlet.
	SB2T02	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
	FDB	TBD[8]	Rhodamine Tracer Study[8]	Determine hydraulic residence time.
Post-Wetland Demonstration	SB2SL[9]	once	Lab[10]	Characterize chemical composition of sludge; evaluate deposition.

Notes:

1. Location IDs are shown on Figure B-2.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.
4. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids, and total and dissolved metals using methods shown in Table B-15.
5. Field water quality measurements of pH, temperature, SEC, ORP, and DO using direct or continuous methods using methods shown in Table B-15.
6. Lab Analyses: Total and Dissolved Metals: Sb, Ba, Be, Cr, Mg, K, Si, Se, Ag, Na, Tl, V; total chloride, total cyanide, total sulfide, and TOC using methods shown in Table B-15.
7. Flow rate measurements will be measured using a factory calibrated electromagnetic flowmeter.
8. Field measurements of Rhodamine WT tracer dye using in-situ calibrated fluorometer using methods shown in Table B-15. See Table B-16 for tracer study details.
9. Six (6) SB No. 2 sludge (SB2SL) characterization sampling locations are SB2SL1A, SB2SL2A, SB2SL3A, SB2SL4A, SB2SL5A, and SB2SL6A. The number represents transect number (perpendicular to flow) and letter represents a point along the transect.
10. Lab Analyses: acid soluble metals and density using methods shown in Table B-15.

Abbreviations:

DO = dissolved oxygen
FDB = concrete flow diversion box
FM02 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SB No. 2
ID = identification
ORP = oxidation reduction potential
SB2EFF = SB No. 2 effluent monitoring location within the Agridrain
SB No. 2 = settling basin number 2
SB2SL1A = SB No. 2 sludge sampling location, transect 1, point A
SB2SL2A = SB No. 2 sludge sampling location, transect 2, point A
SB2SL3A = SB No. 2 sludge sampling location, transect 3, point A
SB2SL4A = SB No. 2 sludge sampling location, transect 4, point A
SB2SL5A = SB No. 2 sludge sampling location, transect 5, point A
SB2SL6A = SB No. 2 sludge sampling location, transect 5, point A
SB2T01 = SB No. 2 influent water temperature monitoring location
SB2T02 = SB No. 2 effluent water temperature monitoring location
SEC = specific electrical conductance
TBD = to be determined

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TABLE B-13
TREATABILITY STUDY OBJECTIVES FOR STANDALONE SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Primary Objective(s)	Specific Objectives[1] (from Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Evaluate passive removal of suspended solids and particulate Fe by a surface flow wetland without primary treatment.	Evaluate passive removal of suspended solids and particulate Fe by a SFW without primary treatment.	• Influent (FDB) and effluent (SFWEFF) TSS and total Fe.	• Compare influent TSS to effluent TSS • Compare influent total Fe to effluent total Fe.	• SFW effectively reduces TSS if effluent TSS is less than influent TSS. • SFW effectively reduces total Fe if effluent total Fe is less than influent total Fe. • If selected as part of the final remedy, removal data will be used during design to estimate SFW sizing required for TSS and Fe removal.
	Reduce total Fe concentrations from as high as 12 mg/L in the influent to less than 0.5 mg/L in the effluent at a flow rate of 20 gpm.	• Influent (FDB) and effluent (SFWEFF) total Fe. • Flow rate into SFW (FM03).	• Compare influent total Fe to effluent total Fe when flow rate through SFW is 20 gpm.	• SFW effectively reduces total Fe if effluent total Fe is less than 0.5 mg/L. • If selected as part of the final remedy, removal data will be used during design to estimate SFW sizing required for TSS and Fe removal.
	Evaluate the surface area required to achieve the desired effluent Fe concentration.	• Influent (FDB) and effluent (SFWEFF) total Fe. • Flow rate into SFW (FM03). • As-built dimensions of SFW.	• Calculate Fe removal rate normalized to surface area. Fe removal rate is: Removal rate = $Q^*(C_{in}-C_{out})$ • Normalize by dividing this rate by the surface area wetted by flow. • Normalized removal rates will also be determined at different flow rates. • Removal rates will not fully account for potential removals due to expected limitations on plant growth during demonstration.	• If selected as part of remedy, normalized Fe removal rate will be used during design to determine size of SFW.
	Observe Fe removal rates as compared to the anticipated removal rate of 4 $g/m^2/d$.	• Influent (FDB) and effluent (SFWEFF) total Fe. • Flow rate into SFW (FM03). • As-built dimensions of SFW.	• Calculate Fe removal rate normalized to surface area. Fe removal rate is: Removal rate = $Q^*(C_{in}-C_{out})$ • Normalize by dividing this rate by the surface area wetted by flow through SFW.	• If selected as part of remedy, normalized Fe removal rate will be used during design to determine size of SFW.
	Quantify the rate of sludge accumulation and the chemical characteristics of the sludge.	• Influent (FDB) and effluent (SFWEFF) TSS concentrations. • Influent (FDB) and effluent (SFWEFF) total metals concentrations. • Post-demonstration sampling and analysis of accumulated sludge.	• Mass balances on TSS and total metals concentrations can be used to determine removal rates, which are equivalent to sludge accumulation rates. Removal rates to be calculated as: Removal rate = $Q^*(C_{in}-C_{out})$ • Metals removal rates will be used to estimate metals composition of accumulated sludge. • Sludge analysis will verify metals composition of accumulated sludge.	• If selected as part of remedy, sludge accumulation rates will be used to estimate O&M requirements for an SFW, and metals composition of sludge will be used to evaluate sludge disposal requirements.
	Determine the effects of vegetation dormancy on Fe removal.	• Visual observations of vegetation status. • Influent (FDB) and effluent (SFWEFF) total Fe. • Flow rate into SFW (FM03).	• Calculate Fe removal rate as: Removal rate = $Q^*(C_{in}-C_{out})$ • Calculate and compare Fe removals for different states of vegetation in SFW.	• Fe removal rates during vegetation is dormant can be used as baseline removal rates for SFW design process.
	Estimate the amount of heat loss through the standalone SF wetland.	• Temperature measurements at influent and effluent ends of SFW (SFWT01and SFWT02, respectively). • Flow rate into SFW (FM03).	• Compare influent and effluent water temperatures at SFW for varying flow rates, water temperatures, and ambient air temperatures.	• Results to be used during design process, if an SFW is selected as part of the remedy. Thermal analysis will be incorporated into system design and O&M procedures to prevent freezing of the SFW and any subsequent unit processes.

TABLE B-13
TREATABILITY STUDY OBJECTIVES FOR STANDALONE SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Primary Objective(s)	Specific Objectives[1] (from Work Plan)	Information Inputs[2,3]	Evaluation Approach[2,3]	Data Use
Evaluate passive removal of suspended solids and particulate Fe by a surface flow wetland without primary treatment.	Observe inlet and outlet flow patterns and velocities to determine if the inlet and outlet structures promote or inhibit settling.	• System inspections and visual observations of SFW. • Flow rate into SFW (FM03). • Tracer test results (i.e., effluent [SFWEFF] tracer concentrations as a function of time). • As-built dimensions of SFW.	• Tracer test to be used to evaluate RTD of SFW. RTD will indicate if non-ideal flow occurs in SFW. • If ponding is observed in the SFW, design of the inlet and outlet structures can be altered or flow rate can be modified. • Visual observations of flow patterns through the SFW.	• If selected as part of the final remedy, flow observations will be considered during design to enhance settling.
	Evaluate the effectiveness, capital and operating costs, and O&M requirements, including accumulated sludge removal requirements and methods, for particulate Fe removal through a SF wetland, which may be employed for a full-scale system.	• Calculated TSS and total Fe removal rates and sludge accumulation rates. • Literature review of sludge removal methods from similar SFWs. • System inspections and visual observations of SFW. • Capital and O&M costs for demonstration SFW.	• Compare TSS and total metals removals under different conditions. • System observations to be used to develop O&M requirements. • Full-scale costs to be estimated by scaling up demonstration operational requirements.	• Information to be used for treatment technology evaluation. • If selected, information to be used during the design process for developing operating procedures and for estimating costs of a full-scale system.

Notes:
1. Objectives for this unit process are described in Section 4.7.2 of the Constructed Wetland Demonstration Treatability Study Work Plan (Atlantic Richfield, 2013).
2. Sampling and monitoring locations shown on Figure B-6.
3. Sampling and monitoring program summarized in Table B-7.

Abbreviations:
Cin = influent concentration
Cout = effluent concentration
Fe = iron
FM03 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of SFW.
$g/m^2/d$. = gram per square meter per day
HDPE = high density polyethylene
HRT = hydraulic residence time
mg/L = milligrams per liter
O&M = operations and maintenance
Q = flow rate
RTD = residence time distribution
SB No. 1 = Settling Basin No. 1
V = volume
TSS = total suspended solids
Fe = iron
SFW = surface flow wetland

TABLE B-14
FIELD SAMPLING PLAN SUMMARY FOR THE STANDALONE SURFACE FLOW WETLAND
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Location ID[1]	Frequency[2]	Operational Parameters	Rationale / Data Use
Demonstration Wetland (12 weeks)	Standalone SFW	semi-monthly[3]	Field Observations	Routine visual observations / system inspection.
	FDB	semi-monthly[3]	Lab[4]	Evaluate loading to SF wetland and treatment performance.
	SFWEFF	semi-monthly[3]	Lab[4], Water Quality[5]	Evaluate treatment performance and evaluate effluent water quality.
	SFWEFF	monthly	Lab[6]	Monitor effluent quality from standalone SF wetland into Pond 18.
	FM03	continuous	Flow Rate[7]	Monitor flow rate into SF wetland for calculating loading rates.
	FDB	continuous	Water Quality[5]	Monitor changes in process chemistry.
	SFWT01	continuous	Water Temperature	Monitor water temperature at inlet.
	SFWT02	continuous	Water Temperature	Monitor water temperature at outlet to evaluate heat loss.
	FDB	TBD	Tracer Study[8]	Determine hydraulic residence time.

Notes:

1. Location IDs are shown on Figure B-6.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequencies will be evaluated and adjusted as appropriate during the course of data collection and analysis to eliminate redundancy or unnecessary sample/data collection.
3. Sampling twice per month, with one additional sample collected one week after startup. Each test run will have samples collected at startup, week one, week two, week four, week six, etc.
4. Lab Analyses: total sulfate, total dissolved sulfide, total suspended solids, and total and dissolved metals using methods shown in Table B-15.
5. Field water quality measurements of pH, temperature, SEC, ORP, and DO using direct or continuous methods using methods shown in Table B-15.
6. Lab Analyses: Total and Dissolved Metals: Sb, Ba, Be, Cr, Mg, K, Si, Se, Ag, Na, Tl, V; total chloride, total cyanide, total sulfide, and TOC using methods shown in Table B-15.
7. Flow rate measurements will be measured using a factory calibrated electromagnetic flowmeter.
8. Field measurements of Rhodamine WT tracer dye using in-situ calibrated fluorometer using methods shown in Table B-15. See Table 16 for tracer study details.

Abbreviations:

DO = dissolved oxygen
FDB = concrete flow diversion box
FM03 = flowmeter inline with the inlet piping from concrete flow diversion box to inlet of standalone SFW
ID = identification
ORP = oxidation reduction potential
SFW = surface flow wetland
SFWEFF = standalone SF wetland effluent monitoring location within the Agridrain
SFWT01 = standalone SFW influent water level and temperature monitoring location
SFWT02 = standalone SFW effluent water level and temperature monitoring location
SEC = specific electrical conductance
TBD = to be determined

TABLE B-15
ANALYTICAL METHODS, VOLUMES, AND LIMITS OF REPORTING
Rico-Argentine Mine Site
Dolores County, Colorado

Parameter	Method Reference	Container	Suggested Volume[1]	Preservation[2]	Limits of Reporting	Maximum Holding Time[3]
Laboratory Analyses - Solids						
Porosity	ASTM F1815	6" Sleeve[4]	Note 4	None	NA	NA
Permeability	ASTM D5084	6" Sleeve[4]	Note 4	None	NA	NA
Density	ASTM D7263	PB	100g	None	NA	NA
Acid Soluble Metals[5] (Rock Matrix)	SOP 7.0	P	50 g	None	5 - 50 ug/L	6 months
Acid Soluble Metals[5] (Mixed Matrix)	SOP 8.0	P	50 g	None	5 - 50 ug/L	6 months
Laboratory Analyses - Water						
Metals[6,7]	EPA 200.7/200.8/245.1	P	250 mL	HNO_3 to pH <2	0.2 - 50 ug/L	28 days for Hg; 6 months for others
Alkalinity	SM 2320B	P	250 mL	None	20 mg/L	14 days
Chloride, Sulfate	EPA 300.0	P	50 mL	None	5 mg/L	28 days
Total Suspended Solids	SM 2540D	P	250 mL	None	5 mg/L	7 days
Total Dissolved Solids	SM 2540C	P	250 mL	None	5 mg/L	7 days
Total Organic Carbon	SM 5310C	P	250 mL	H_2SO_4 to pH <2	5 mg/L	28 days
Biological Oxygen Demand (BOD)	SM 5210B	P	1000 mL	None	1 mg/L	48 hours
Total Sulfide	SM 4500E-S2	P	500 mL	NaOH to pH >10	0.05 mg/L	7 days
Total Cyanide	SM 4500E-CN	P	500 mL	NaOH to pH >10	5.0 mg/L	14 days
Phosphorus	EPA 365.4	P	100 mL	H_2SO_4 to pH <2	0.1 mg/L	28 days
Nitrate-Nitrite – Nitrogen	EPA 353.2	P	100 mL	H_2SO_4 to pH <2	0.1 mg/L	28 days
Ammonia – Nitrogen	EPA 350.1	P	500 mL	H_2SO_4 to pH <2	0.1 mg/L	28 days

TABLE B-15
ANALYTICAL METHODS, VOLUMES, AND LIMITS OF REPORTING

Rico-Argentine Mine Site
Dolores County, Colorado

Parameter	Method Reference	Container	Suggested Volume[1]	Preservation[2]	Limits of Reporting	Maximum Holding Time[3]
Field Analyses - Water						
pH	SOP 3.0 (Field meter or Sondes)	P	100 mL	None	0.2 unit	15 minutes
Conductivity					0.1 µS/cm	15 minutes
Temperature					0.1 °C	15 minutes
Oxidation Reduction Potential					20 mV	15 minutes
Dissolved Oxygen					0.2 mg/L	15 minutes
Turbidity		P	250 mL	None	1 NTU	15 minutes
Total Dissolved Sulfide	SOP 3.0 (YSI Photometer)	P	100 mL	None	0.01 mg/L	ASAP
Bromide (Tracer)	SOP 3.0 (Field ISE)		50 mL	None	1 mg/L	7 days
Rhodamine (Tracer)	SOP 3.0 (Field Fluorometer)	P	20 mL	None	1 ug/L	15 minutes

Notes:

1 . Additional volume will be provided for laboratory QC samples (e.g., matrix spike, laboratory duplicate) as necessary.
2 . Samples should be stored at a temperature ranging from 0°C - 6°C.
3 . Maximum holding time references the lesser of the respective analyte holding times published by U.S. EPA.
4. Relatively undisturbed samples for analysis of porosity and permeability will be collected using a soil core sample in a brass sleeve in accordance with SOP 13.0 – Soil, Rock, Sediment, and Matrix Sampling.
5. Soluble metals include aluminum (, arsenic, barium, cadmium, cobalt copper, iron, lead, manganese , molybdenum, nickel and zinc
6. Total and dissolved metals include aluminum, arsenic, cadmium, calcium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel and zinc.
7. Additional total and dissolved metals for monthly testing of effluent samples discharging to Pond 18 are antimony, barium, beryllium, chromium, magnesium, potassium, silicon, selenium silver, sodium, thallium, and vanadium.
8. Shipment of BOD samples should occur on same day as sample collection to meet short holding time.

Abbreviations:

°C = degree Celsius
ASAP = as soon as possible (from time of sample collection)
BOD = biological oxygen demand
HNO_3 = nitric acid
H_2SO_4 = sulfuric acid
ISE = Ion Selective Electrode
µS/cm = micro Siemens per centimeter
mV = millivolts
mg/L - milligrams per liter
mL = milliliters
N/A = not applicable
NTU = nephelometric turbidity units
P = Polyethylene
PB = Plastic "zip-top" bagQC = quality control
SOP = standard operating procedure
ug/L = micrograms per liter
U.S. EPA = United States Environmental Protection Agency

TABLE B-16
TRACER STUDIES
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Unit Process	Tracer	Location ID	Figure Reference	Expected HRT[1] (hours)	Sampling Frequency[2]	Samples to Collect	Comments
Colonization (4 weeks)	SSF Wetland	NaBr or LiCl	PSFWEFF	B-4	17.2	NA	NA	NaBr or LiCl will be poured into Agridrain at PSFWEFF and samples will be collected using an automatic samplers from the MPs and in the Agridrain at ACINF. Tracer results will be evaluated to determine hydraulic residence time and residence time distribution. Not all samples will be analyzed. SEC will be measured in the SSFWMPs and in ACINF to determine which samples will be analyzed for NaBr or LiCl in the field.
			SSFWMP[3]			one sample every hour per MP	17 per MP	
			ACINF	B-5		one sample every hour per MP	17	
Wetland Demonstration (12 weeks)	SB No.1	Rhodamine	FDB	B-2	17.6	NA	NA	Rhodamine dye will be poured into the FDB and Rhodamine concentrations will be measured Agridrain at SB1EFF using in-situ calibrated fluorometer. Tracer results will be evaluated to determine hydraulic residence time.
			SB1EFF			one sample every 30 minutes	35	
	Polishing SF Wetland	Rhodamine	SB1EFF	B-3	5.6	NA	NA	Rhodamine dye will be poured into Agridrain at SB1EFF and Rhodamine concentrations will be measured in Agridrain at PSFWEFF using in-situ calibrated fluorometer. Tracer results will be evaluated to determine hydraulic residence time.
			PSFWEFF			one sample every 30 minutes	11	
	SSF Wetland	NaBr or LiCl	PSFWEFF	B-4	17.2	NA	NA	NaBr or LiCl will be poured into Agridrain at PSFWEFF and samples will be collected using an automatic samplers from the MPs and in the Agridrain at ACINF. Tracer results will be evaluated to determine hydraulic residence time and residence time distribution during 30 gpm test run. Not all samples will be analyzed. SEC will be measured in the SSFWMPs and in ACINF to determine which samples will be analyzed for NaBr or LiCl in the field. Approximately 20% of the samples collected will be sent to the laboratory for confirmation analysis.
			SSFWMP[3]			one sample every hour per MP	17 per MP	
			ACINF	B-5		one sample every hour per MP	17	
	SSF Wetland	NaBr or LiCl	PSFWEFF	B-4	TBD[4]	NA	TBD[4]	NaBr or LiCl will be poured into Agridrain at PSFWEFF and samples will be collected using an automatic samplers from the MPs and in the Agridrain at ACINF. Tracer results will be evaluated to determine hydraulic residence time and residence time distribution during second test run. Not all samples will be analyzed. SEC will be measured in the SSFWMPs and in ACINF to determine which samples will be analyzed for NaBr or LiCl in the field. Approximately 20% of the samples collected will be sent to the laboratory for confirmation analysis.
			SSFWMP[3]			one sample every hour per MP	TBD[4]	
			ACINF	B-5		one sample every hour per MP	TBD[4]	

TABLE B-16
TRACER STUDIES
Rico-Argentine Mine Site
Dolores County, Colorado

Phase/ Est. Duration	Unit Process	Tracer	Location ID	Figure Reference	Expected HRT[1] (hours)	Sampling Frequency[2]	Samples to Collect	Comments
Wetland Demonstration	Aeration Channel	Rhodamine	ACINF	B-5	0.15	NA	NA	Rhodamine dye will be poured into Agridrain at ACINF and Rhodamine concentrations will be measured in outlet control structure at ACEFF using in-situ calibrated fluorometer. Tracer results will be evaluated to determine hydraulic residence time.
			ACEFF			one sample every 1 minute	15	
	Rock Drain	Rhodamine	ACEFF	B-6	15.7	NA	NA	Rhodamine will be poured into outlet control structure at ACEFF and Rhodamine concentrations will be measured in the MPs and in the Agridrain at RDEFF. Tracer results will be evaluated to determine hydraulic residence time and residence time distribution.
			RDMP[5]			one sample every 30 minutes per MP	31 per MP	
			RDEFF			one sample every 30 minutes	31	
SB No. 2 Testing	SB No.2	Rhodamine	FDB	B-2	17.6	NA	NA	Rhodamine dye will be poured into the FDB and Rhodamine concentrations will be measured Agridrain at SB2EFF using in-situ calibrated fluorometer. Tracer results will be evaluated to determine hydraulic residence time.
			SB2EFF			one sample every 30 minutes	34	
Standalone SF Wetland Testing	Standalone SF Wetland	Rhodamine	FDB	B-6	15.4	NA	NA	Rhodamine dye will be poured into the FDB and Rhodamine concentrations will be measured Agridrain at SFWEFF using in-situ calibrated fluorometer. Tracer results will be evaluated to determine hydraulic residence time.
			SFWEFF			one sample every 30 minutes	31	

Notes:
1. Hydraulic residence times are calculated based on designed dimensions, side slopes, porosity, and matrix composition for a target flow rate of 30 gallons per minute.
2. The actual sampling frequency may vary to due site conditions, changing flow rates, or monitoring observations. Additionally, sampling frequency may be adjusted to capture peak concentrations and for accurate mass balance
3. Eleven (11) SSF wetland monitoring ports are SSFWMP01, SSFWMP02, SSFWMP03, SSFWMP04, SSFWMP05, SSFWMP06, SSFWMP07, SSFWMP08, SSFWMP09, SSFWMP10, and SSFWMP11.
4. Six (6) rock drain monitoring ports are RDMP01, RDMP02, RDMP03, RDMP04, RDMP05, and RDMP06.
5. HRT can not be estimated because the flow rate for second test run has not been determined.

Abbreviations:
ACEFF = aeration channel effluent monitoring location within the outlet control box
ACINF = aeration channel influent monitoring location within the Agridrain water level control structu
FDB = concrete flow diversion box
HRT = hydraulic residence time
ID = identification
LiCl = lithium chloride
MP = monitoring port
NA = not applicable
NaBr = sodium bromide
PSFWEFF = polishing SF wetland effluent monitoring location within the Agridrain
RDMP = rock drain monitoring ports
RDEFF = rock drain effluent monitoring location within the Agridrain
SB No. 1 = settling basin number 1
SF = surface flow
SFWEFF = standalone SF wetland effluent monitoring location within the Agridrain
SSF = subsurface flow
SSFWMP = subsurface flow wetland monitoring ports
TBD = to be determined

TABLE B-17
HYDROGEN SULFIDE MONITORING ACTIVITIES
Rico-Argentine Mine Site
Dolores County, Colorado

H_2S Monitoring Event	Unit Process	Figure Reference	Location / ID	Rationale
Monthly Survey	Polishing SF Wetland	B-3	PSFWEFF	Monthly H_2S surveys will be conducted to assess concentrations around the perimeter of the SSF wetland, aeration channel, and rock drain and the associated monitoring locations of each unit process using a calibrated multi-gas meter.
	SSF Wetland	B-4	SSFWMP[1]	
	SSF Wetland	B-4	Perimeter of SSF Wetland	
	Aeration Channel	B-5	Perimeter of Aeration Channel	
	Aeration Channel	B-5	ACEFF	
	Rock Drain	B-5	RDMP[2]	
	Rock Drain	B-5	RDEFF	
	Rock Drain	B-5	Perimeter of Rock Drain	
	Aeration Channel / SSF Wetland	B-1	H2S01	H_2S concentrations will be recorded monthly to confirm fixed H_2S monitoring device measurements and to assess if the fixed monitoring devices need to be calibrated and/or sensors need to be replaced.
	Aeration Channel / SSF Wetland	B-1	H2S02	
	Aeration Channel	B-1 / B-5	H2S03	
	Aeration Channel	B-1 / B-5	H2S04	

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TABLE B-17
HYDROGEN SULFIDE MONITORING ACTIVITIES
Rico-Argentine Mine Site
Dolores County, Colorado

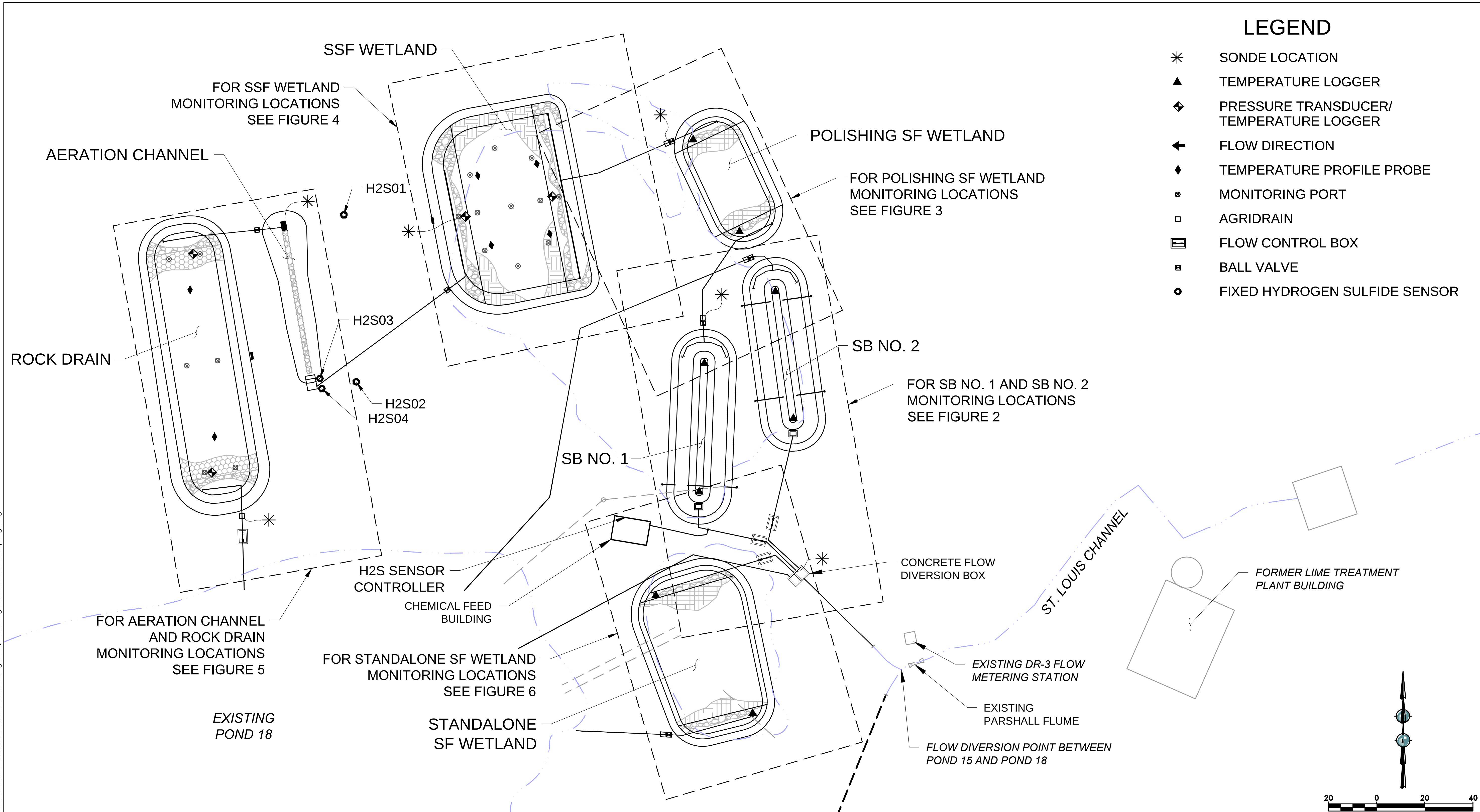
H_2S Monitoring Event	Unit Process	Figure Reference	Location / ID	Rationale
Fixed H_2S Monitoring	Aeration Channel / SSF Wetland	B-1	H2S01	Continuously monitor and data log the H2S concentrations on the outer perimeter of the aeration channel to protect the general public.
	Aeration Channel / SSF Wetland	B-1	H2S02	Continuously monitor and data log the H2S concentrations on the outer perimeter of the aeration channel to protect the general public.
	Aeration Channel	B-1 / B-5	H2S03	Continuously monitor and data log the H2S concentrations from the SSF wetland effluent at the inlet to the aeration channel to protect on-site workers.
	Aeration Channel	B-1 / B-5	H2S04	Continuously monitoring and data log H2S concentrations at the inlet to the aeration channel near the ground surface where concentrations are expected to be the highest.

Notes:

1. Eleven (11) SSF wetland monitoring ports are SSFWMP01, SSFWMP02, SSFWMP03, SSFWMP04, SSFWMP05, SSFWMP06, SSFWMP07, SSFWMP08, SSFWMP09, SSFWMP10, and SSFWMP11.
2. Six (6) rock drain monitoring ports are RDMP01, RDMP02, RDMP03, RDMP04, RDMP05, and RDMP06.

Abbreviations:
ACEFF = aeration channel effluent monitoring location within the outlet control box
ID = identification
PSFWEFF = polishing SF wetland effluent monitoring location within the Agridrain
RDMP = rock drain monitoring ports
RDEFF = rock drain effluent monitoring location within the Agridrain
SF = surface flow
SSF = subsurface flow
SSFWMP = subsurface flow wetland monitoring ports

FIGURES



GENERAL LAYOUT

Rico - Argentine Mine Site
Dolores County, Colorado

By: ARC	Date: 07/26/2013	Project No. SA11161315
amec		Figure B-1

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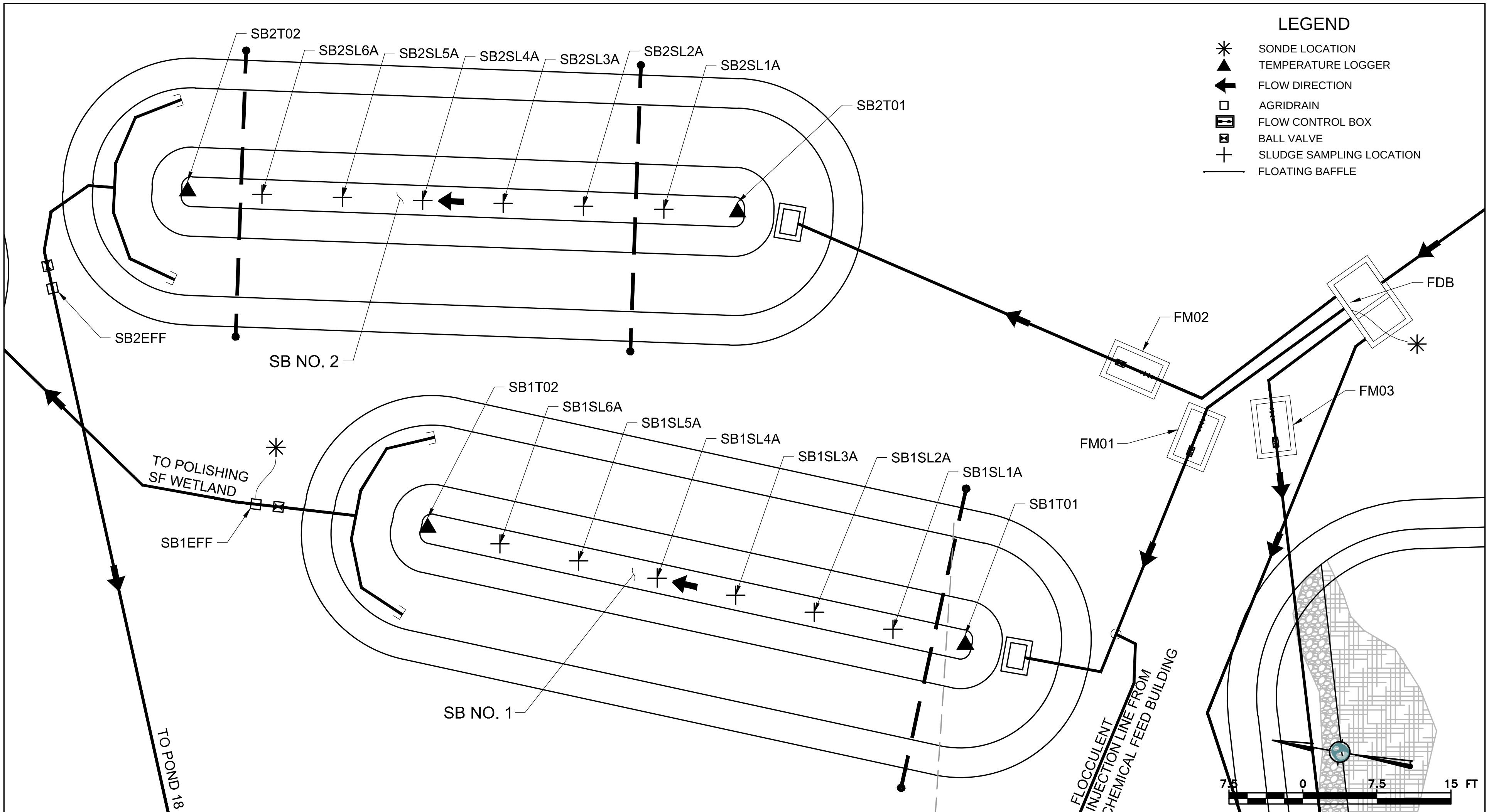

SB NO. 1 AND SB NO. 2
MONITORING LOCATIONS
Rico - Argentine Mine Site
Dolores County, Colorado

By: ARC	Date: 07/26/2013	Project No. SA11161315
amec		Figure B-2

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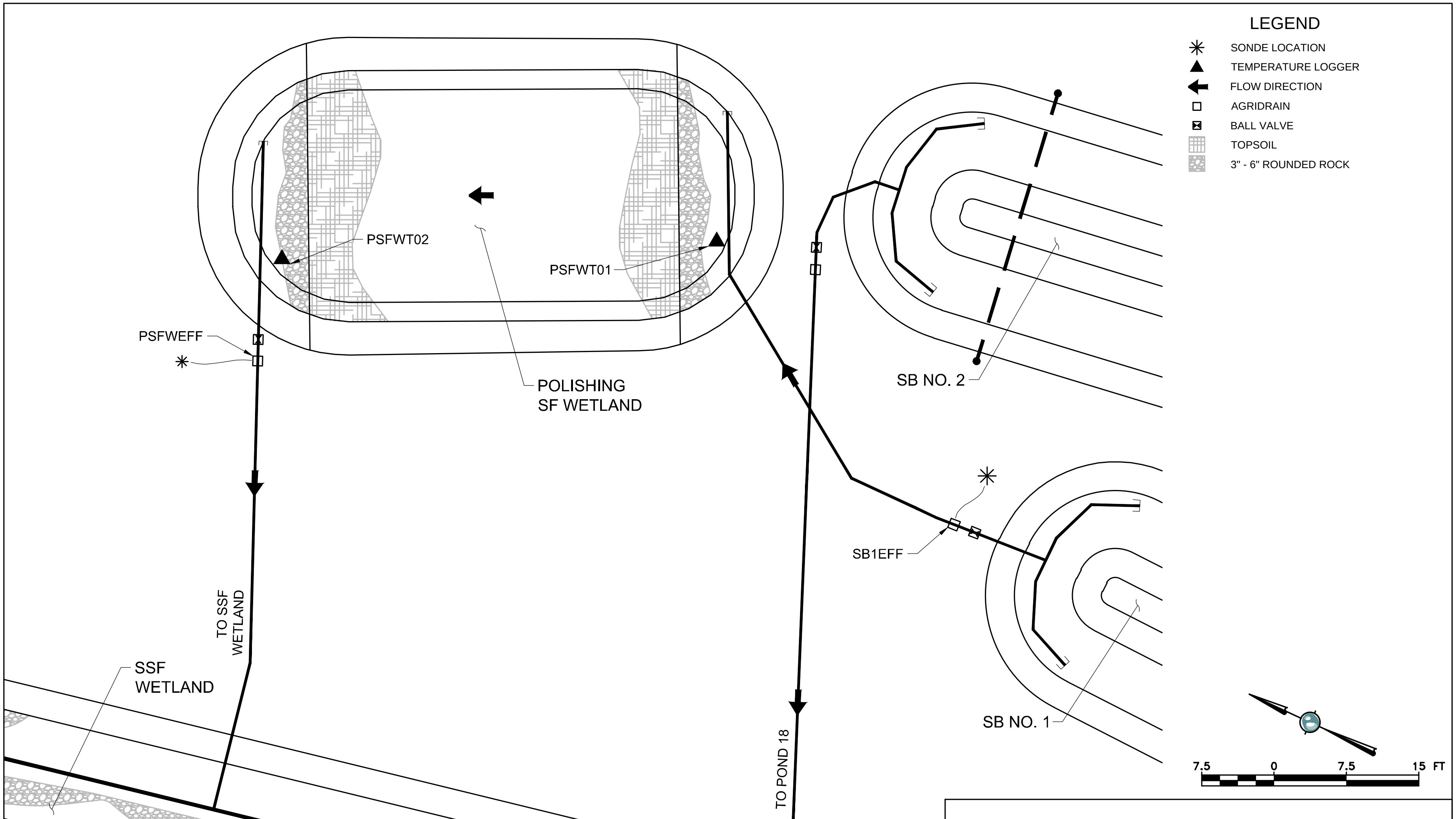

POLISHING SF WETLAND
MONITORING LOCATIONS
Rico - Argentine Mine Site
Dolores County, Colorado

By: ARC	Date: 07/26/2013	Project No. SA11161315
amec		Figure B-3

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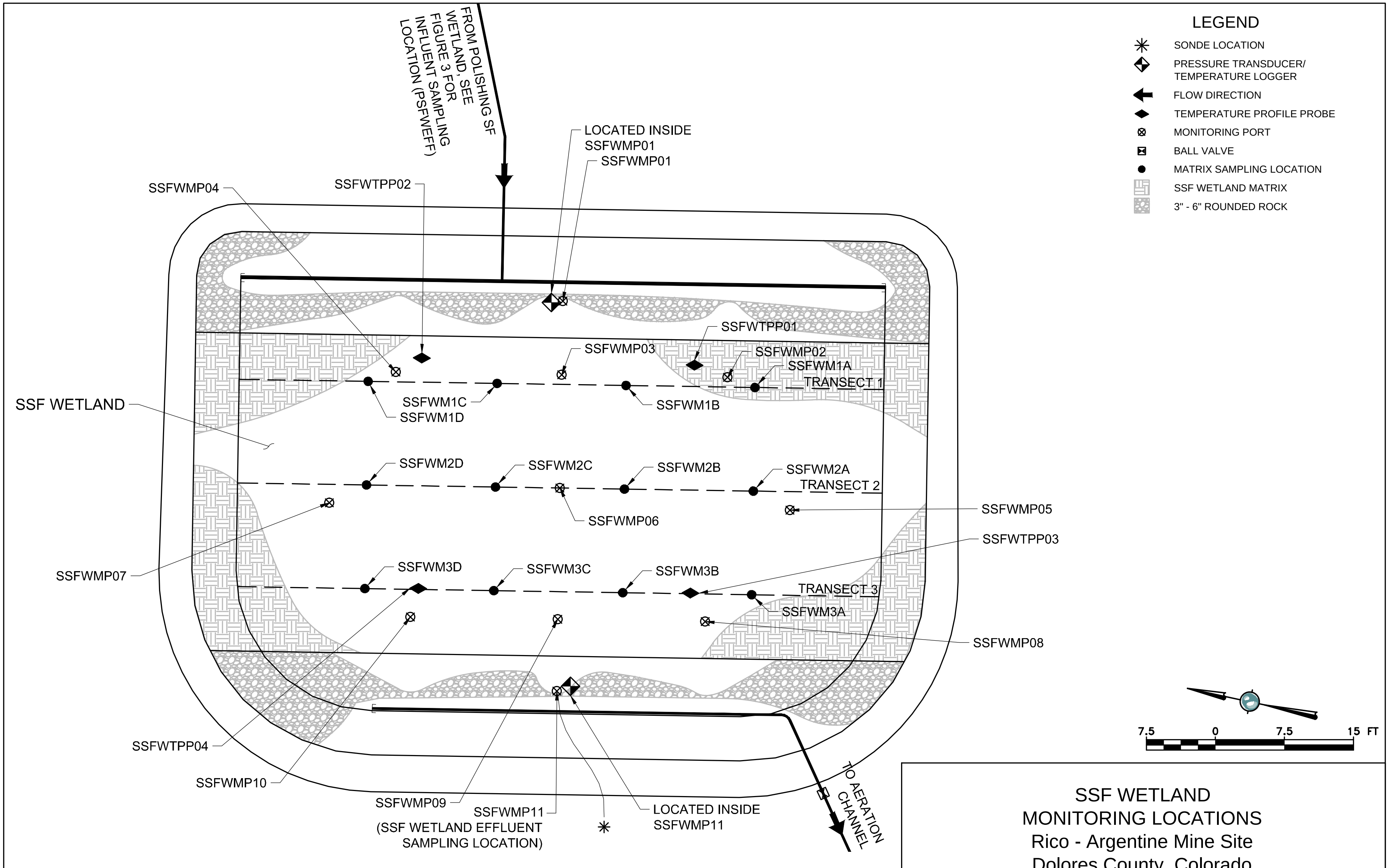

SSF WETLAND
MONITORING LOCATIONS
Rico - Argentine Mine Site
Dolores County, Colorado

By: ARC	Date: 07/26/2013	Project No. SA11161315
amec		Figure B-4

Plot Date: 10/03/13 - 9:02am, Plotted by: mark.crater
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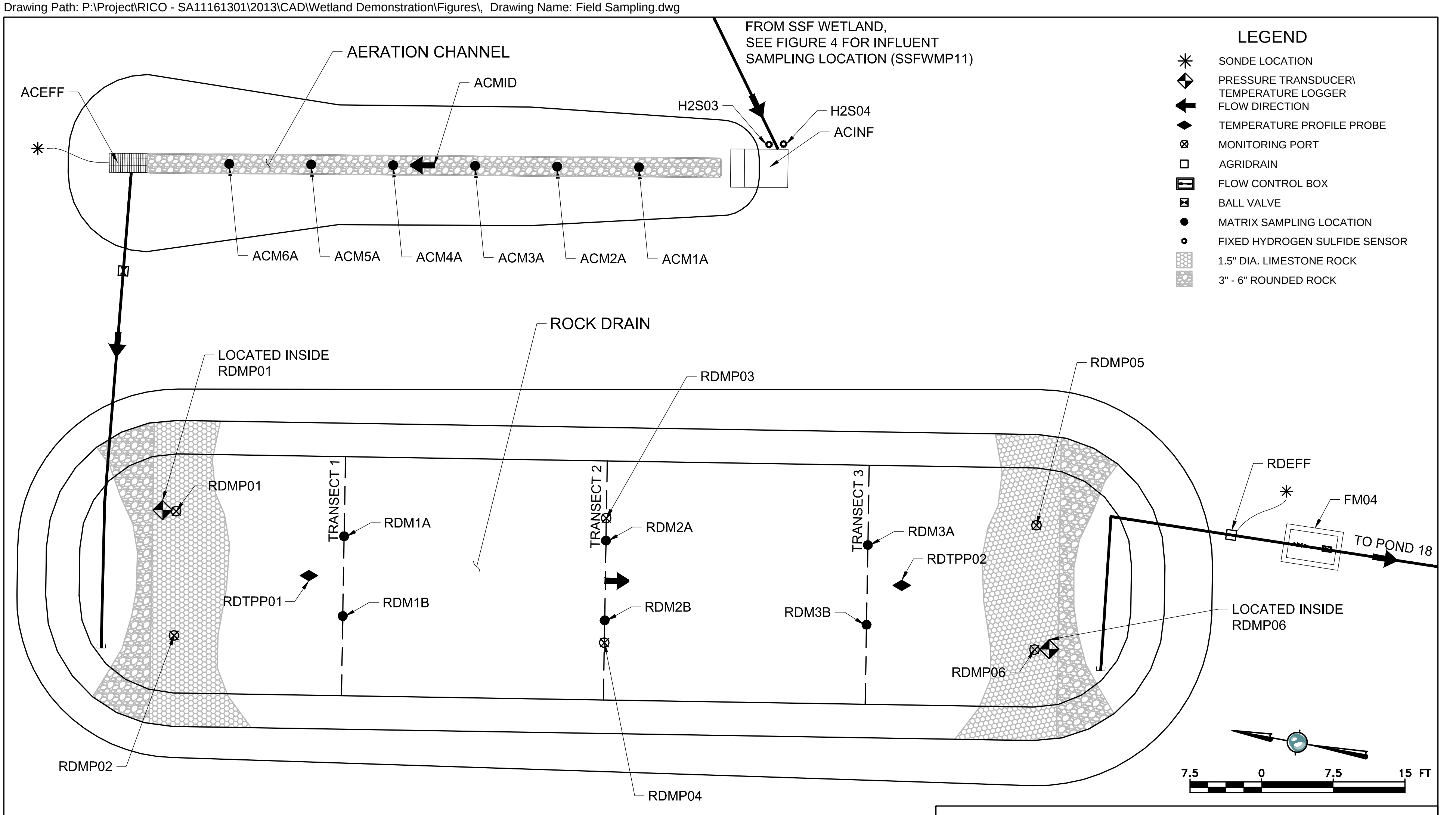
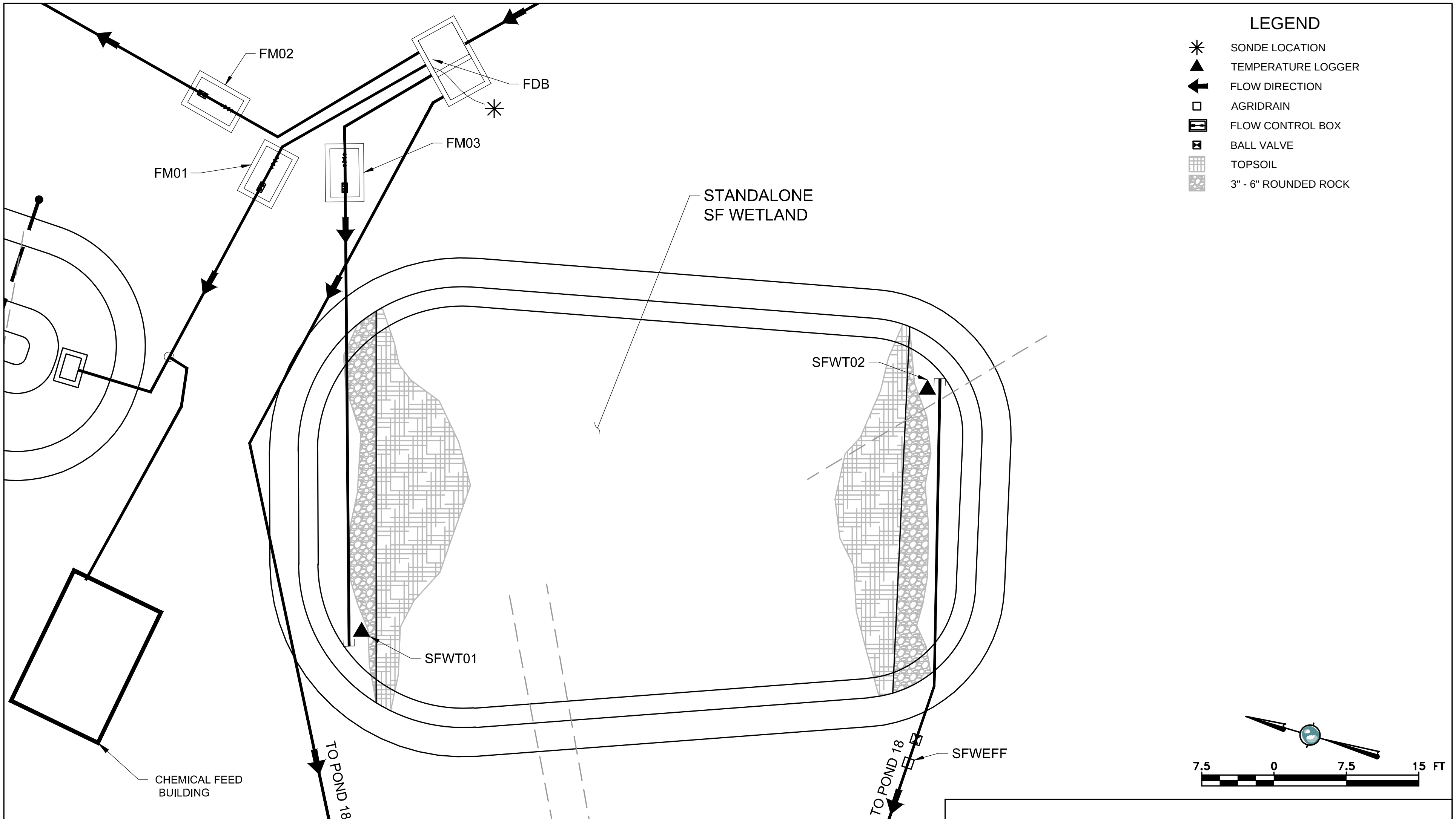


AERATION CHANNEL AND ROCK
DRAIN MONITORING LOCATIONS
Rico - Argentine Mine Site
Dolores County, Colorado

By: ARC	Date: 07/26/2013	Project No. SA11161315
		Figure B-5

Plot Date: 10/03/13 - 9:04am, Plotted by: mark.crater
Drawing Path: P:\Project\RICO - SA11161301\2013\CAD\Wetland Demonstration\Figures\, Drawing Name: Field Sampling.dwg



STANDALONE SF WETLAND
MONITORING LOCATIONS
Rico - Argentine Mine Site
Dolores County, Colorado

By: ARC	Date: 07/26/2013	Project No. SA11161315
amec		Figure B-6

ATTACHMENT A

Standard Operating Procedures

1.0 – FIELD DOCUMENTATION AND SAMPLE HANDLING

Purpose and Scope: The purpose of this document is to present procedures for field documentation and sample handling. It includes a description of how to fill out a Daily Field Record (DFR), Sample Control Log, and Chain-of-Custody (COC). It also describes procedures for sample labeling, handling, preservation, packaging, and shipping.

Equipment: The following equipment will be needed depending on specific task and will be used, as appropriate, when packing or shipping samples:

- Sample Bottles
- Sample Labels
- Custody Seals
- Fine Tipped Permanent Markers
- Nitrile gloves or other appropriate gloves
- Sealable storage bags
- Bubble wrap or appropriate packing materials
- Blue ice or double bagged ice
- Coolers suitable for sample shipment and holding ice
- Strapping/packaging tape and shipping labels, if needed
- Camera with spare memory chip and batteries

Documentation: DFR (attached)
Sample Control Log (attached)
COC Document (attached) or laboratory equivalent
Sampling Records
Maps/plot plan
Camera
Photograph Log (attached)

1.1 FIELD AND SAMPLE DOCUMENTATION

Documentation of the conditions and procedures used to collect, treat, and handle samples and field data is one of the most important aspects of any sampling or monitoring program. Proper documentation provides sources to determine the integrity and applicability of the data. Carefully document all field activities in a field logbook or on data sheets. Field logbooks shall be bound with consecutively numbered pages and shall be written in with permanent ink. At the end of each field season, the original field log books and all original data sheets will be kept in the AMEC office, located in Rancho Cordova, California. Field activities shall be recorded in sufficient detail so that field activities can later be reconstructed from the notes. Any changes to the notes in the field logbook shall be made by drawing a single line through the incorrect material and initialing and dating the mark-out.

1.1.1 Daily Field Record (DFR)

Documentation of observations and data acquired in the field provide information on sample acquisition, field conditions at the time of sampling, and a permanent record of field activities. Record field observations and data collected during the investigation with waterproof ink on DFR sheets (Attached). A new DFR should be completed for each day or when a separate phase of work is initiated. DFR should be single sided.

The DFRs will include the following information, as appropriate.

- Project and Task Number
- Project Name
- Location of sample (if samples are collected)
- Date
- Time
- Field Activity
- Weather Conditions
- Personnel Onsite, Company Name, and Time Onsite
- Personal Safety Checklist
- Description of Work Performed
- Description of Waste Generated

Information written within the area delineated “Description of Work Performed” should include the following:

- Sample identification number(s)
- Time of sample
- Description of sample
- Number and volume of samples
- Field observations

- List other associated paperwork related to the activity (e.g., boring log, sample control log, maps, etc.)
- Decontamination procedures

Photographs should be taken of pertinent activities that occur during the investigation. These should include capturing images that clearly demonstrate that the goals of the project are being met. They should also be taken of any changes in procedures or unexpected findings that occur in the field. Items of scale should be included in the view of the photograph (i.e., ruler, clipboard, etc.). A running log of the photographs with a description of each photograph should be included on a photo log attached to the DFR. All photos should include the following information on the photo log: ID number generated by the camera, date the photo was taken, initials of the photographer, location of the photo, direction of view and any additional comments or descriptions.

Strike out changes or deletions in the field book or on the data sheets with a single strike mark and be sure that the original information remains legible. Each page should be completely filled without any blank lines, if necessary write “Not Applicable” or “NA” on blank lines. The field logbook or field data sheets should be signed daily by the author of the entries.

1.1.2 Sample Control Log

If samples are collected during the field investigation, a sample control log must be filled out documenting the sample location, study area, sample matrix, sample ID, sample date, sample time, sample collector, sample depth, sample type, code (whether the sample is a normal environmental sample or which type of quality assurance/quality control [QA/QC] sample it is), additional notes (i.e. sample turnaround time, COC remarks, details about the sample or analysis, etc.), which laboratory the samples were sent to and the date they were shipped.

1.1.3 Chain of Custody (COC)

During sampling activities, a “paper trail” of sample custody must be maintained from the time the samples are collected until laboratory data are issued. Information on the custody, transfer, handling, and shipping of samples should be recorded by the sampling personnel on an Atlantic Richfield COC form. If a project or task-specific COC form is not available (i.e., with specific analytes and analytical methods listed), an equivalent form provided by the destination laboratory can be used instead. A COC form will be completed for each set of samples collected daily. At a minimum, every COC will contain the following information:

- Sampling Personnel's name and signature
- Project name
- Date and time of collection (corresponding to the respective field sampling record and sample control log)
- Field sample identification code and sample matrix
- Analyses/Methods requested
- Number of containers and any preservative used
- Signature of persons relinquishing custody, dates, and times
- Signature of persons accepting custody, dates, and times (exclusive of FedEx, UPS or similar service)
- Method of shipment
- Shipping tracking numbers/waybill identification number (as appropriate)

Additional Atlantic Richfield project tracking information to be completed on the COC includes the following:

- Name of the lead regulatory agency
- Name and contact information of the environmental business manager
- Name and contact information of the consultant and Project Manager
- Enfos proposal number and the stage and activity level of the project
- Level of data package requested

An example Atlantic Richfield COC is provided as an attachment and should be strictly followed as it is important that COCs are completed with consistent information. A copy of each COC form will be retained in the project files.

1.1.4 Sampling Records

Sampling records have been customized for each general sampling activity and are included in the respective SOPs. The associated sampling record should be filled out during the sampling process. Pertinent information varies with each type of sampling, but at a minimum, the following information should be filled out for each sample:

- Project name
- Project task description
- Location of sample
- Sample identification code (Sample ID)
- Time of sample collection
- Results of any field measurements, such as depth to water, pH, temperature, specific electrical conductance, dissolved oxygen, turbidity, discharge, etc.
- Instrument/s used to measure field measurements
- Any QA/QC samples that were collected
- Field observations, such as color, odor or texture of the sample, etc.
- Field test results (if applicable)
- Method of sampling
- Name and signature of sampler

If field measurements are recorded for a sample collected for laboratory analysis, the time recorded for the field measurements shall be consistent with the sample collection time. If a multiparameter sonde is deployed to continuously measure water quality parameters at a sampling location, water quality parameters for a sample collected for laboratory analysis can be obtained from the downloaded data files. The parameters selected to represent the sample extracted from the electronic data file will be recorded at the time closest to the sample collection time. For example, if a sample for laboratory analysis is collected at 10:36 and parameters were recorded by the multiparameter sonde at 11:00, the measurements recorded by the sonde at 11:00 should be used to represent the sample.

1.2 Sample Labeling

After sample collection, the samples will be labeled with self-adhesive labels with all necessary information added using waterproof ink. Make sure the labels are completed so that the information is legible and consistent. At a minimum, each sample label will contain the following information:

- Project name

- Sample ID Date (mmddyy) and 24-hour clock time (hh:mm) of sample collection
- Analyses required
- Preservatives, if applicable
- Sampler's initials

The information on the sample label shall match respective record on the COC and sample control log.

Each sample will be assigned a unique identification code according to sample location, date, and depth (if applicable). For example, if a sample is collected from the 517 Shaft at a depth of 450 feet below the shaft collar on August 20, 2013, the sample ID will be “517Shaft450130820”.

Field blanks and duplicates shall be labeled such that the sample location is not identified to the lab. All field QC samples will be given the sample identifier “QC”, but will not identify the true QC sample type. To account for more than one QC sample collected on any given day, the sample identifier will be followed by a sequential number. For example, if a field duplicate sample is collected from the 517 Shaft, as given in the example above,, and it is the first QC sample collected on this day, the sample ID will be “QC1130820”. The identity of field QC samples will be traceable through the sample control log and the project database.

1.3 SAMPLE HANDLING

General sample handling procedures shall include the following:

- Always make field measurements on a separate sub-sample, not on the sample that is sent to the laboratory for analysis. Discard the sub-sample after the measurements have been made.

- Do not use containers that have been used in the laboratory to store concentrated reagents or have been previously used as sample containers. Use only new containers that are certified clean by the manufacturer or laboratory for sample collection.

- For water samples, do not allow the inner portion of sample containers and caps to come into contact with bare hands, gloves, tubing or other objects.

- Keep sample containers in a clean environment away from dust, dirt, and fumes. Field personnel shall wear disposable nitrile gloves when collecting water samples. Gloves must be changed out between each water sample collected.

- Do not let any samples, including water, vegetation, or invertebrate samples, stand in the sun. Store all samples in coolers with blue or double bagged ice;
- COC procedures will be strictly adhered to during sample collection, transportation, and laboratory handling to assure the identity of the samples. Improper sample and data handling and inadequate COC procedures affect the credibility and acceptability of analytical results, regardless of their accuracy or precision. COC documentation will document processing of the sample from the time of collection to the time of analysis.

If overnight storage of collected water samples is required prior to shipment to a laboratory, the samples will be stored in accordance to procedures described in Section 1.6.

1.4 SAMPLE PRESERVATION

Sample preservation will depend on the analytical method to be performed and the sample matrix. Preservation methods and preservatives for each analytical method and matrix will be presented in the St. Louis Tunnel Discharge Source Mine Water Treatability Study Quality Assurance Project Plan. The planned sample preservation activities, sample container size and type, and analytical methods should be confirmed with the laboratory well in advance of collecting samples.

For all water samples and select soil samples, the laboratory will supply clean, unused, and pre-preserved sample containers as appropriate. If containers are preserved, the type of preservative should be clearly labeled on each bottle. Do not rinse out sample containers. The preservative (lab or field added) will be documented on the sample label and COC. Samples collected in non-laboratory certified clean containers (e.g., via split spoon, direct push, drive, or grab methods), will be decontaminated prior to use in accordance to procedures described in SOP 4.0, Equipment Decontamination.

1.5 SAMPLE PACKAGING AND SHIPPING

If samples are required to be chilled, they will be stored during the day, or overnight, in ice-cooled containers.

Samples collected during the morning may be temporarily stored in a refrigerator (if available) until shipment in the afternoon. All samples stored in the coolers or the refrigerator will be documented on the sample control log. When samples are being packaged for shipment, the procedures listed below will be followed.

1. Field personnel will visually screen each sample in the cooler for loose surface contamination, and confirm that each sample is listed on the sample control log and the COC.

2. Samples will be packed with abundant packaging material to minimize the potential for damage during shipment. If samples need to be chilled, they will be placed in sealable plastic bags and immediately placed on ice in an insulated cooler. Insulated coolers can be provided by the contract laboratories. Sample containers will be placed right side up in a cooler with double bagged ice for delivery to the laboratory.

3. The completed COC will be signed, scanned and emailed to the lab to inform them about the sample(s) they will be receiving. The scans will be saved for project records. Then, the COC will be placed in a plastic sealable storage bag which will be taped to the inside cover of the cooler. The COC form will be shipped with the cooler and serve as the legal documentation of sample custody for the field and laboratory.

4. If samples are to be transported overnight via Federal Express or United Parcel Service, all ice must be double bagged to prevent leakage. The lid of the cooler must be taped shut with custody seals. The cooler will then be taped shut using clear shipping tape. Failure to seal all potential leaks may result in rejection of delivery by the courier. If samples are shipped on a Friday then Saturday delivery stickers must be attached to the coolers on all four sides as well as the top. Make sure to check the overnight delivery space on the shipping papers. Affix the label on the top or side of the cooler.

5. Samples will typically be shipped to the laboratory daily. Copies of the completed COC will be kept in the field office by the field manager.

6. Sample shipment will be scheduled to prevent exceeding any required holding period. Failure to submit samples for analysis within the required holding times will prompt appropriate corrective and preventive action measures.

1.6 OVERNIGHT STORAGE

If the hold time allows, samples may be stored overnight as long as they are properly packaged, labeled, placed in a secure location. If chemical analysis is to be performed on the sample, it must be stored at no more than 6°C or 39°F, but above freezing. Samples will be kept in a cooler or refrigerator locked in a secure location and shipped the following day. When placing samples into the refrigerator, make sure it is plugged in and turned on and set at the appropriate temperature. Samples should not be kept for more than a week or longer than analytical holding times allow. If samples are kept overnight, chain of custody procedures must still be followed.

1.7 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
01	ARC	Section 1.1.1 DFR should be single sided. Section 1.1.4 Sampling Records – add text regarding field measure collection time and parameters recorded using the sonde. Formatted Sample Control Log (1c)	6/4/13	LL 6/6/13

ATTACHMENTS

- Daily Field Record (DFR)
- Sample Control Log
- Atlantic Richfield Chain-of-Custody (COC) Record
- Photograph Log

DAILY FIELD RECORD

Project and Task Number:	Date:
Project Name:	Field Activity:
Location:	Weather:

PERSONNEL: Name	**Company**	**Time In**	**Time Out**

PERSONAL SAFETY CHECKLIST

	Safety-toed Boots		Hard Hat		Radio
	Nitrile/Leather Gloves		Safety Glasses		Ear Plugs

DRUM I.D.	**DESCRIPTION OF CONTENTS AND QUANITY**	**LOCATION**

TIME	**DESCRIPTION OF WORK PERFORMED**

DAILY FIELD RECORD (continued)

Project and Task Number:	Date:

TIME	DESCRIPTION OF WORK PERFORMED

SAMPLE CONTROL LOG

Project Name: ____ Task Name: ____

Project & Task No.: ____ Week of: _________________ Crew: ____

Sample Location	Sample Matrix	Sample ID	Sampling Date	Sample Time	Sample Collector Initials	Sample Depth (feet bgs)	Sample Type[1] / Code[2]	Additional Notes[3]	Lab	Date Sent to Lab

1. Sample Types include: Grab, Composite, Incremental, or Autosampler
2. Code includes: Normal Environmental (NE), Field Duplicate (FD), Field Blank (FB), Equipment Blank (EB), and Matrix Spike/Matrix Spike Duplicate (MS/MSD)
3. Include notes such as: turnaround time, sample location details, handling notes, Chain-of-Custody remarks, etc.

Atlantic Richfield Company
A BP affiliated company

Laboratory Management Program LaMP Chain of Custody Record

Page _____ of _____

BP/ARC Project Name: ____________________ **Req Due Date (mm/dd/yy):** __________ **Rush TAT:** Yes ____ No ____

BP/ARC Facility No: ____________________ **Lab Work Order Number:** ____________________

Lab Name:	BP/ARC Facility Address:	Consultant/Contractor:
Lab Address:	City, State, ZIP Code:	Consultant/Contractor Project No:
Lab PM:	Lead Regulatory Agency:	Address:
Lab Phone:	California Global ID No.:	Consultant/Contractor PM:
Lab Shipping Accnt:	Enfos Proposal No:	Phone:
Lab Bottle Order No:	Accounting Mode: Provision ____ OOC-BU ____ OOC-RM ____	Email EDD To:
Other Info:	Stage: Activity:	Invoice To: BP/ARC ____ Contractor ____

BP/ARC EBM:	**Report Type & QC Level**
EBM Phone:	Standard ____
EBM Email:	Full Data Package ____

Lab No.	**Sample Description**	**Date**	**Time**	**Matrix**				**No. Containers / Preservative**							**Requested Analyses**										**Comments**
				Soil / Solid	Water / Liquid	Air / Vapor		Total Number of Containers	Unpreserved	H_2SO_4	HNO_3	HCl	Methanol												Note: If sample not collected, indicate "No Sample" in comments and single-strike out and initial any preprinted sample description.

	Relinquished By / Affiliation	**Date**	**Time**	**Accepted By / Affiliation**	**Date**	**Time**
Sampler's Name:						
Sampler's Company:						
Shipment Method: Ship Date:						
Shipment Tracking No:						

Special Instructions:

THIS LINE - LAB USE ONLY: Custody Seals In Place: Yes / No	Temp Blank: Yes / No	Cooler Temp on Receipt: __________°F/C	Trip Blank: Yes / No	MS/MSD Sample Submitted: Yes / No

PHOTOGRAPH LOG

Project Name: ______________________________ Task Name: ______________________________

Project & Task No.: ______________________________ Camera No: ______________________________

Camera Assigned ID #	Date	Photographer Initials	Location	Direction of View	Additional Comments

2.0 – SAMPLE COLLECTION TECHNIQUES AND DATA COLLECTION STRATEGIES

Purpose and Scope: The purpose of this document is to describe general sampling techniques and data collection strategies.

Equipment:
Nitrile gloves or other appropriate gloves
Measuring Wheel or Tape Measure
Flag markers
Hand-Held Global Positioning System (GPS) device;
Camera
Marking flags
Marking paint

Documentation:
Daily Field Record (DFR)
Photo Log
Maps

Specific sample techniques, strategies, locations and frequency will be presented in the work plans. However, in the event that the work plans require that sample collection techniques and data collection strategies must be determined in the field (e.g. pre-investigation planning, mapping, waste sampling), the procedures within this SOP should be followed.

2.1 SAMPLE COLLECTION TECHNIQUES

Three basic types of sample collection techniques are: Grab, Composite, and Incremental Samples. These techniques are described below:

- A grab sample is defined as a discrete sample representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

- A composite sample is a non-discrete sample composed of more than one sample collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

- Incremental sampling (IS) is a structured composite sampling protocol that reduces sampling error associated with compositional and distributional heterogeneity of the analyte of interest in soil or sediments. The IS protocol consists of defining sampling or decision units, collecting a minimum of 30 individual soil samples from randomly selected locations within each unit, and submitting the samples to the laboratory for processing (drying, compositing, sieving, and sub-sampling) in a specified manner prior to laboratory analysis.

2.2 DATA COLLECTION STRATEGIES

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling. Each of the strategies is explained in the following:

- Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site.
- Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established.
- Judgmental sampling involves collection of samples only from the portion of the site most likely to be contaminated.

A combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, and the level/type of information desired.

2.3 SAMPLE LOCATION DOCUMENTATION

Once a sample location is chosen and the sample has been collected, the location will be temporarily staked or marked until it has been surveyed. Additionally, 3 to 4 photos of the location should be taken so the location is well documented. The photos should be documented on a photo log (SOP 1.0 – Field Documentation and Sample Handling).

Wooden stakes, steel fence posts with safety caps, survey whiskers, pin flags with the name of the location written in permanent marker, or survey whiskers can be driven into the ground to show the location. It is not recommended that spray paint be used to mark locations as it may get washed off or brushed over by dirt and rocks. Spray paint may be used as a temporary location marker; however, the spray paint marker should either be surveyed or replaced as soon as possible so the location is not lost.

For samples and activities that require high accuracy survey data such as the installation of borings for subsurface mapping, the installation of monitoring wells, piezometers, and monitoring ports for water level measurement, and the installation of surface monitoring monuments, survey activities will be subcontracted to a third party that has a current California survey license and is capable to surveying within a 100^{th} of a foot. All surveys shall be completed using the most recent version of the State Plane Coordinate System. The surveyor will obtain accurate coordinates and elevations of the sample locations within several weeks after the installation activities.

If only sub-meter accuracy for vertical and horizontal survey information is needed, a hand-held GPS device may be used in place of a licensed surveyor to obtain general coordinates of locations and activities.

1.4 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
01	ARC	Minor edits. Section 2.1- added Incremental Sampling	6/5/13	LL 6/6/13

3.0 – FIELD MEASUREMENTS - WATER

Purpose and Scope: The purpose of this document is to provide procedures for measuring the water levels from wells and collecting field parameters in surface water and groundwater. It includes instructions on the setup, field procedures, and how to fill out the associated field forms.

Equipment:

pH Meter and Electrode
Specific Electrical Conductance (SEC) Meter
Dissolved Oxygen (DO) Meter
Oxidation Reduction Potential (ORP) MeterThermometer or Temperature Probe
Fluorometer
Fluorometer Sample Analysis Cuvette
Photometer and associated sample vials and reagents
Ion Specific Electrodes (ISE) and ISE Meter
Peristaltic Pump
0.45-micron Large-Capacity Filter Cartridges
Silicone Tubing
Polyethylene Tubing
Distilled Water
Deionized Water
Spray Water Bottles
1% Liquinox Solution
Sample Cup or Beaker
Calibration Standards for Each Meter
Miscellaneous Field Tools:
- Socket for Flush-Mounted Wells
- Cutting Shears
- Spare Combination Locks
- Christie Box Opening Tool
- Flat Head Screwdriver
- Extra Batteries
- Nitrile Gloves

Documentation:

Daily Field Record (DFR)
Water Level Monitoring Record (attached)
Well Sampling Record (attached)
General Water Sampling Record (attached)
Multiparameter Meter Calibration Sheet (attached)
Single Point Calibration Sheet (attached)
Multi-Point Calibration Sheet (attached)
Temperature Corrected Calibration Standards Data Sheet (attached)
Individual Procedures for YSI Photometer Tests for Commonly Used Test Methods (attached)
YSI Photometer Test Method Operating Ranges (attached)

This Standard Operating Procedure (SOP) describes the general methodology for water level measurement from wells, measuring field parameters in water, and performing field analytical tests on water samples. Field parameters typically consist of pH, specific electrical conductance (SEC), turbidity, oxidation reduction potential (ORP), temperature, and dissolved oxygen (DO). Analytical tests may be performed in the field and could include but are not limited to alkalinity, dissolved zinc, sulfide, iron, bromide, chloride, sodium, and Rhodamine. Refer to the manufacturer's recommendations for specific operational procedures and calibration requirements for each type of field instrumentation and field analytical methods described in this SOP.

All field measurements of water will be performed by appropriately trained field staff under the guidance of a California-licensed Professional Geologist or Professional Engineer.

3.1 SETUP AND EQUIPMENT CALIBRATION

Prior to taking any field measurements or performing field tests, sampling personnel will assemble all necessary equipment and calibration standards. All instruments to be used will be checked and/or calibrated per the manufacturer's instructions and as often as recommended by the manufacturer to ensure they are in proper working condition. Calibration data including the concentration of the calibration standard(s) and the calibration reading for the check standard(s) will be recorded on a Multiparameter Meter Calibration Sheet, Single Point Calibration Sheet, and/or a Multi-Point Calibration Sheet as applicable (attached).

3.2 WATER LEVEL MEASUREMENT

Water levels may be measured in monitoring wells, piezometers, and water supply wells or in other types of structures where water can accumulate (e.g. mine shafts, constructed wetland monitoring ports, ponds). For ease of use, "well" will refer to any structure in which the water level is being measured. Open the well by removing the lid on the well box and remove the well cap. When opening the well box and removing the cap, be sure to keep your head away from the top of the open casing to avoid inhaling any fumes that may reside within the well.

Decontaminate all water level measurement equipment as described in SOP 4.0 – Equipment Decontamination prior to inserting any instruments into the well.

Water level measurements will be referenced to a known elevation datum. The measuring point at the top of the well casing (generally the north side of the casing) or some other permanent reference point will be permanently marked and surveyed. Measurements will be consistently taken from the same marked point. Water levels will be measured with an electrical sounding device, a hydrocarbon interface measuring device, or equivalent device.

The static water level will be measured in each well using an electronic water level indicator. Measurements will be made by recording the depth-to-water (DTW) and repeating the measurement until at least two consecutive depth readings within 0.01-foot are measured. The final water level measurement for each well will be recorded in the field on a Water Level Monitoring Record.

When attempting to collect a DTW measurement, if a vacuum or a pressure buildup is detected upon opening the airtight well cap, an initial depth to water level will be obtained and the well will be allowed to equilibrate for approximately 3-5 minutes. After the field geologist or engineer has used professional judgment to determine that the water table is stable, another DTW measurement within the well will be obtained. Additional measurements will be obtained at 3-5 minute intervals until at least two consecutive depth readings are within 0.01-foot.

The field geologist or engineer may also measure the depth-to-bottom (DTB), or the depth to the bottom of the well by lowering a measuring device (e.g., sounding device) to the bottom of the well. If the sounding device has a “zero measuring point” at a place other than the tip of the probe, the difference in measurement will be added or subtracted from the reading so that the recorded value is an accurate measurement from top of casing to DTB.

At the completion of the DTW and possible DTB measurements, the field geologist or engineer will wipe down the down-hole equipment with a new paper towel to remove excess water or debris from the tool and decontaminate as appropriate.

3.3 FIELD PARAMETERS

Generally, a multi-parameter water quality meter (YSI is the brand that is commonly used) will be used to measure field parameters. The following describes measuring field parameters of pH, SEC or EC, temperature, turbidity, ORP, and DO using an YSI meter or similar equipment.

3.3.1 pH

The general procedures for the operation, calibration, and maintenance of the field pH meter and its accessories are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations. Manufacturer's specifications and recommendations should be followed when using the pH meter.

Prior to use each day, the pH meter should be examined for cleanliness, for defects, and for any possible need of repair. The examination should include the battery and electrode. Once the pH meter is observed to be in correct operating condition, it should be calibrated using a minimum of a three-point calibration using 4.0, 7.0, and 10.0 pH standard solutions (purchased from a reputable vendor, and non-expired). pH meter should be calibrated to the temperature corrected standard solution values. Temperature corrected pH standard values are included in the Temperature Corrected Calibration Standards Data Sheet (attached). Calibration of the instrument should not be calibrated out of range. If calibration value is out of range do not except calibration. A value outside of acceptable range of the meter indicates a problem in the calibration process, standards used, or sensor malfunction. Instrument user manual should be referenced for troubleshooting procedures.

Prior to beginning the calibration, the expiration date for each of the calibration standards will be checked. Standard solutions that have expired will not be used and will be properly disposed in accordance with SOP 5.0 - IDW Disposal. A record of the pH reading for each concentration of standard and any calibration notes will be denoted on the Multiparameter Meter Calibration Sheet (attached).

3.3.2 Specific Electrical Conductance

The general operation, calibration, and maintenance for use of the SEC meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations. Manufacturer's specifications and recommendations should be followed when using the conductivity meter.

Prior to use each day, the SEC meter should be examined for cleanliness, for defects, and for possible need of repair. The examination should include the battery and the probe. Once the conductivity meter is observed to be in correct operating condition, it should be calibrated using a minimum standard solution of 1,000 micro-Siemens (µS/cm) at 25 degrees Celsius (° C) (purchased from a reputable vendor). When calibrating the SEC meter, temperature correction of the standard solution is not necessary because SEC is the electrical conductivity normalized to 25 ºC. If electrical conductivity is calibrated on the meter, the meter should be calibrated to the temperature corrected calibration standard. Temperature corrected 1,413 µS/cm standard values are included in the Temperature Corrected Calibration Standards Data Sheet (attached). Calibration of the instrument should not be calibrated out of range. If calibration value is out of range do not except calibration. A value outside of acceptable range of the meter indicates a problem in the calibration process, standards used, or sensor malfunction. Instrument user manual should be referenced for troubleshooting procedures.

Prior to beginning the calibration, the expiration date for the calibration standard will be checked. Standard solutions that have expired will not be used and will be properly disposed of in accordance with SOP 5.0 – IDW Disposal. A record of SEC reading and any calibration notes will be denoted on the Multiparameter Meter Calibration Sheet.

3.3.3 Temperature

The operation procedure of the thermometer or temperature probe for use in the field is included in the instruction manual provided with the equipment. Prior to use each day, examine the thermometer/probe for cleanliness, defects, and any possible need of repair. Temperature calibration is done by the manufacturer.

3.3.4 Turbidity

The general procedures for the operation, calibration, and maintenance of a field turbidity meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations. Turbidity meters used can either be part of a multiparameter unit or a single turbidity meter.

Prior to use each day, the turbidity meter should be examined for cleanliness, for defects, and for possible need of repair. The examination should include the battery. Once the turbidity meter is observed to be in correct operating condition, it should be blanked with a 0.0 NTU standard solution then calibrated using a standard solution close to the expected sample range (purchased from a reputable vendor). Prior to beginning the calibration, the expiration date for each of the calibration standards will be checked. Standard solutions that have expired will not be used and will be properly disposed in accordance with SOP 5.0 – IDW Disposal. Acceptance limits for each standard and any calibration notes will be denoted on the Multiparameter Meter Calibration Sheet.

If the turbidity meter reads in AU instead of NTU, then the sample is too turbid to collect a measurement. For documentation purposes, it should be noted that the meter is reading >500 NTU instead of noting the value in AU.

3.3.5 Oxidation Reduction Potential

The general procedures for the operation, calibration, and maintenance of the field ORP are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use, examine the ORP meter for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the ORP meter is observed to be in correct operating condition, it should be calibrated using a minimum standard solution of 100 milliVolts (mV) (purchased from a reputable vendor). Temperature corrected ORP standard values for Aurical Company and Zobell's standards are included in the Temperature Corrected Calibration Standards Data Sheet (attached). If other another ORP calibration standard is used, the temperature corrected values from the manufacture must be obtained prior to use. If calibration value is out of range do not except calibration. A value outside of acceptable range of the meter indicates a problem in the calibration process, standards used, or sensor malfunction. Instrument user manual should be referenced for troubleshooting procedures.

Prior to beginning the calibration, the expiration date for the calibration standard will be checked. Standard solutions that have expired will not be used and will be properly disposed of in accordance with SOP 5.0 – IDW Disposal. A record of the ORP reading and all calibration notes will be denoted on the Multiparameter Meter Calibration Sheet (attached).

3.3.6 Dissolved Oxygen

The general procedures for the operation, calibration, and maintenance of a field DO meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations.

Prior to use, examine the DO meter for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe. Once the DO meter is observed to be in correct operating condition, it should be calibrated using distilled water and the barometric pressure of the atmosphere where the DO is being collected. If calibration value is out of range do not except calibration. A value outside of acceptable range of the meter indicates a problem in the calibration process, standards used, or sensor malfunction. Instrument user manual should be referenced for troubleshooting procedures. All calibration notes must be recorded on the Multiparameter Meter Calibration Sheet (attached).

DO is generally calibrated in percent (%) but the sample readings must be recorded in mg/L. DO levels vary based by temperature, true barometric pressure, and salinity. True barometric pressure has not been corrected to sea level. Note that most weather service readings are not true and have been corrected to sea level and must be uncorrected. An approximate formula to convert corrected barometer pressure to the true barometer pressure is presented below.

$$\text{True BP} = \text{Corrected BP} - \frac{2.5 \text{ x Local Altitude (feet above sea level)}}{100}$$

The general saturation levels range from 8 to 14 mg/L DO. If the meter reads above the saturation level for the current temperature and pressure, it should be recalibrated. If it is still out of range, the membrane and solution should be changed.

3.3.7 Pressure Transducer

The general procedures for the operation, calibration, and maintenance of pressure transducer used to measure changes in water levels are included in the instruction manual provided with the equipment. In addition, the manual provides information regarding specific operational parameter that must be programmed prior to using the pressure transducer. These parameters could include but are not limited to site elevation, latitude, and density of water in order to convert the pressure measurement into a water depth or water level.

Field personnel should be familiar with software required for programming and downloading data from the pressure transducers prior to use.

3.3.8 Multiparameter Meters

Multiparameter meters such as YSI 556 MPS, YSI 6920 multiparameter sondes, Multiparameter Troll 9500, or similar may be used for grab or continuous water quality monitoring. Prior to use, instruction manual provided with the equipment should be review. The general procedures for the operation, calibration, and maintenance of multiparameter sondes are included in the instruction manual provided with the equipment.

Field personnel should be familiar with software required for programming and downloading data from the multiparameter meters prior to use.

If possible calibration checks will be performed approximately weekly by measuring the monitoring location water quality parameters with calibrated multiparameter meter and compared to the in-situ multiparameter sonde water quality measurements. If the relative percent difference between the sonde and the calibrated meter is greater than 20%, the sensor should be further evaluated by placing the sensor in a known calibration standard and recalibrated if necessary.

This calibration check may not be applicable to certain sensors, such as ORP. Similar or identical calibrated ORP sensors have shown to read significantly different values (up to 100 - 150 mV) in the same source water and read the same value in a calibration standard. Variations in ORP measurements can be due to lack or low concentration of redox active agent in the environmental water (YSI Environmental, 2005). In general, ORP sensors with long term exposure to sample water will provide the most accurate ORP measurement because of the length of time required for the ORP electrode to equilibrate with source water. However, maintenance should be performed periodically on sonde ORP sensor electrode to ensure field consistency and accuracy. Sensor electrode cleaning should be performed in accordance with manufactures' recommendations.

3.3.9 Water Quality Probe Cleaning, Maintenance, and Sensor Replacement

Water quality sensors should be maintained per the manufactures recommendations. Special care should be implemented to sensors exposed to fouling environments (anoxic, caustic, etc.). If visual fouling is observed on sensors, sensors should be cleaned to ensure field consistency and accuracy.

Approximately yearly, annual factory maintenance will be performed to the water quality meters. Meters used for continuous water quality monitoring may require more frequent factory maintenance and sensor replacement. The sensor replacement schedule will be contingent on frequency of sensor use.

3.3.10 Rhodamine

A field or in-situ fluorometer could be used to measure Rhodamine dye concentrations during tracer studies. The operation and calibration procedure for the fluorometer for use in the field is included in the instruction manual provided with the equipment. Prior to use each day, examine the fluorometer for cleanliness, defects, and any possible need of repair. The examination should include the battery and probe.

Once the fluorometer is observed to be in correct operating condition, it should be calibrated using at least a two point calibration. The standards should target the lower and upper operation range of the instrument. If a YSI 6130 optical Rhodamine fluorometer sensor is used, the lower range calibration standard will be deionized water to target 0 mg/L and Rhodamine dye used for the tracer study will be used to create a standard in the range of 125 – 175 mg/L to target the upper operation range of the sensor. Follow the operating instructions provide in the instrument manual for proper calibration. A record of the fluorometer calibration, including all readings and calibration notes shall be denoted on the Multi-Point Calibration Sheet (attached).

3.3.11 Tagout

If any of the above water quality meters are found to be above or below the range of concentration for check standard, the equipment must be locked out and tagged out so it will not be used inadvertently. A replacement meter shall be obtained and properly calibrated while the out of range equipment is repaired.

3.3.12 Procedures for Testing a Sample

Samples will be tested for the above water quality parameters by triple-rinsing a small container with the sample water before filling the container with the sample to be tested or by placing the multiparameter meter with probe guard installed directly into sample water. If sample container is filled to measure parameters, ensure all the appropriate probes will be submerged. The probes shall remain in container or source water until parameters stabilize.

In some cases a flow-through cell may be used while collecting water quality parameters. If a flow-through cell is used it must be decontaminated in between each sample location (see SOP 4.0 – Equipment Decontamination). Do not use detergents when decontaminating probes. Only rinse probes with fresh or distilled water.

Once the water quality readings have stabilized, but before the temperature of the sample begins to change (less than 5 degrees Celsius difference from the initial temperature reading) because of the ambient temperature, the values for each parameter will be recorded on the appropriate sampling record (attached). If the sampling and monitoring program requires the measurement of aerobic and anaerobic sample water, the aerobic samples should be measured before the anaerobic water samples. If anaerobic sample water is measured first, the response to changes in ORP will be very slow and it is likely that ORP will not stabilize.

3.4 Field Analytical Methods for Alkalinity, Zinc, Sulfide, and Iron

Field measurement of alkalinity, zinc, sulfide, and iron can be made with a YSI 9500 Photometer. The photometer operation procedures for use in the field are included in the instruction manual provided with the meter. Prior to use each day, the photometer should be examined for cleanliness, defects, and any possible need of repair, or if the battery or test vials need to be replaced.

The field test methods for alkalinity, zinc, sulfide, and iron are attached which include the respective reagent's and testing protocol for each method. Prior to running a photometer field test, analyze a blank sample by filling a test vial with the water to be sampled to allow for the photometer to compensate for the inherent color of the sample. Each test method has its own reaction time period and sample should be analyzed immediately after the reaction period has lapsed. If the concentration detected using the desired field method exceeds the operating range of the photometer for a given method, the sample shall be diluted and re-analyzed. Dilution procedures are described in Section 3.6.

Calibration checks should be performed at least weekly to test the operational performance of the photometer. The calibration check will be performed by testing the transmittance of four known color standard. The table below describes the color standards with the corresponding wavelength and transmittance value.

Standard No.	Standard Color	Wavelength (nm)	Transmittance (%)
33783/A	Clear	0	0
33783/B	Yellow	450	47.1
		500	68.3
33783/C	Pink	550	51.6
		570	70.3
33783/D	Green	600	60.9
		650	44.5

To perform the calibration test select Test Method Phot.0. for Transmittance. First run standard 33783/A as the blank. Test the remaining standards for transmittance using the ↑ or ↓ key to select the appropriate wavelength designated in the table above for each color standard and take photometer reading in usual manner per photometer instructions. Record and compare transmittance results to the table above and if the transmittance recorded is greater than or less than 2%, the calibration of the meter is not in operable range and troubleshooting shall be conducted. Standards should be retested confirming the correct wavelength for each standard was selected. If transmittance results are still not within range the photometer shall be locked out and tagged out using the procedures described in Section 3.3.11 and serviced by a YSI service center for proper calibration.

3.5 FIELD ANALYTICAL METHODS USING ION SPECIFIC ELECTRODES

Concentration of various ions in aqueous solution can be measured in the field using Ion-Specific Electrodes (ISE). The operation procedure for the ISE is included in the instruction manual provided with the equipment. Prior to use each day, examine the ISE for cleanliness, defects, and any possible need of repair.

If the electrodes are in frequent use, the membrane surface can be left exposed to open air protected by a clean beaker. For long term storage, membrane on the electrode should be protected by covering the membrane with the cap provided with the electrode.

Ionic strength adjustment buffers should be added to all samples and calibration standards to normalize the ionic strength of the solutions to minimize interferences.

Once the ISE is observed to be in correct operating condition, establish a multi-point calibration curve. ISE calibration standards are prepared at known concentrations. Typically the calibration standards created will be 1000 parts per million (ppm), 100 ppm, 10 ppm, 1 ppm, and 0.1 ppm. However, if the concentration range is known, calibration standards will be created closely bracketing the know concentration range. The measured mV readings for each standard solution is plotted against the actual activity on a logarithmic X-axis. The calibration curve should be linear in terms of mV response per decade of concentration change. If the calibration is not linear, troubleshooting should be performed as discussed in the operating instructions.

A record of the ISE calibration, including all readings and all calibration notes shall be denoted on the Multi-Point Calibration Sheet (attached).

3.6 SAMPLE DILUTION

A sample will have to be diluted if the concentration is detected above the operating range of the respective testing equipment. The dilution of sample may be an iterative process until the proper dilution ration is obtained. The goal of dilution is to obtain a reading within the working range of the instrument; the concentration reading is neither below the detection limit, nor above the working range. For example, a 1:100 sample dilution may conducted first by adding 1 part sample to 99 parts deionized water for a total of 100 parts (1:100). If the resulting value is near or below the detection limit, a dilution of 1 part sample to 49 parts deionized water for a total of 50 parts (1:50) will be conducted. The instrument reading of the diluted sample is multiplied by the dilution factor to determine the final concentration. Record the results on the Sampling Record along with the dilution factor (i.e., ratio).

3.7 References

YSI Environmental, 2005. Tech Note: Measuring ORP on YSI 6-Series Sondes: Tips, Cautions and Limitations.

3.8 Revision Log

Revision #	Author	Description of Change (Section #)	Date	Reviewer
01	ARC	Section 3.3 – revised calibration procedures and DO calibration procedures to calibrate using true barometric pressure Section 3.3.7 – added section for use of pressure transducers Section 3.3.8 – added section for use of Multiparameter meters Section 3.3.9 – added section on probe maintenance procedures Section 3.3.10 – added calibration standards for YSI Rhodamine sensors Section 3.4 – revised photometer field methods and included calibration check procedures Section 3.5 – revised ISE field methods Section 3.6 – revised sample dilution procedures. Revised field forms and added Multi-Point Calibration Sheet	6/5/13	LL 6/6/13

ATTACHMENTS

- Water Level Monitoring Record
- Well Sampling Record
- Grab Groundwater Sampling Record
- Multiparameter Calibration Sheet
- Single Point Calibration Sheet
- Multi-Point Calibration Sheet
- Individual Procedures for YSI Photometer Tests for Commonly Used Test Methods
- YSI Photometer Test Method Operating Ranges

WATER LEVEL MONITORING RECORD

amec

Project Name: ______________________________ Project and Task Number: __________________________

Date: _____________ Measured by: __________________ Instrument Used: __________________________

Note: For you convenience, the following abbreviations may be used.

P = Pumping I = Inaccessible D = Dedicated Pump WL = Water Level
ST = Steel Tape ES = Electric Sounder MP = Measuring Point DTW = Depth to Water
Assumed Dry = DTW Measurement Below Estimated Bottom of Screen DTB = Depth to Bottom

Well No.	Time	Water Level Below MP (feet)	Depth to Bottom Below MP (feet)*	Remarks

*When using a Solinst WL Meter, add 0.27’ to measurement to account for the “zero measuring point” in the middle of the probe

WELL SAMPLING RECORD

Well ID: ______	**Initial Depth to Water:** ______
Sample ID: ______	**Total Depth of Well:** ______
Sample Date: ______ **Sample Time:** ______	**Well Diameter:** ______
Sample Depth: ______	**Total Volume Removed (gal):** ______
Project and Task No.: ______	**Purged By:** ______
Project Name: ______	**Method of Purging:** ______ **Sampling:** ______
Date: ______	**Pump and Tubing Type:** ______

Time	DTW (feet btoc)	Cum. Vol. (gal.)	Temp. (°C) [+/- 10%]	SEC (µS/cm) [+/- 3%]	DO (mg/L) [+/- 0.3 mg/L]	pH (units) [+/- 0.1]	ORP (mV) [+/- 10 mV]	Tur-bidity (NTU)	Remarks (color, odor, sediment, approx. purge rate, etc.)

Working Ranges for Frequently Used YSI 9300 Test Methods

Sulfide: 0.01 (DL) – 0.5 mg/L — Fe: 0 (DL) – 10 mg/L

Alkalinity M & P: 10 (DL) – 500 mg/L — Zinc: 0.02 (DL) – 4.0 mg/L

Field Test Method	Result (mg/L)	Dilution Factor	**Final Result:** (multiply by 100 for 1:100 dilution or 50 for 1:50 dilution, etc.) **If result is below working range of meter, report as < DL** **If result is above working range, dilute sample**

QA/QC Sampling & QA/QC Field Test Results

QA/QC Type (duplicate, rinsate blank, field blank)	QA/QC Sample ID	QA/QC Sample Time	Photometer QA/QC Initial Results (mg/L)	Dilution Factor	Final Result (mg/L)

Notes:

______

______

______

Instrument(s) Used (model or unit no.): ______

(see Instrument Calibration form dated ______ for calibration details)

Samplers Name:	**Samplers Signature:**

WELL SAMPLING RECORD

amec

Well ID: ______________________ **Date:** ______________________

Time	DTW (feet btoc)	Cum. Vol. (gal.)	Temp. (°C) [+/- 10%]	SEC (μS/cm) [+/- 3%]	DO (mg/L) [+/- 0.3 mg/L]	pH (units) [+/- 0.1]	ORP (mV) [+/- 10 mV]	Tur-bidity (NTU)	Remarks (color, odor, sediment, approx. purge rate, etc.)

Notes:

GENERAL WATER SAMPLING RECORD

amec

Location ID: ______________________________ **Location Type:** ______________________________

Sample ID: ______________________________ **Project and Task No.:** ______________________________

Sample Date: __________ **Sample Time:** ____________ **Project Name:** ______________________________

Method of Sampling: ______________________________ **Sampled By:** ______________________________

Time	**Temp.** (°C)	**SEC** (μS/cm)	**DO** (mg/L)	**pH** (su)	**ORP** (mV)	**Remarks** (color and sediment)

Working Ranges for Frequently Used YSI 9300 Test Methods

Sulfide: 0.01 (DL) – 0.5 mg/L Fe: 0 (DL) – 10 mg/L
Alkalinity M & P: 10 (DL) – 500 mg/L Zinc: 0.02 (DL) – 4.0 mg/L

Field Test Method	**Result (mg/L)**	**Dilution Factor**	**Final Result:** (multiply by 100 for 1:100 dilution or 50 for 1:50 dilution, etc.) **If result is below working range of meter, report as < DL** **If result is above working range, dilute sample**

QA/QC Sampling & QA/QC Field Test Results

QA/QC Type (duplicate, rinsate or field blank)	**QA/QC Sample ID**	**QA/QC Sample Time**	**Photometer QA/QC Initial Results (mg/L)**	**Dilution Factor**	**Final Result (mg/L)**

Notes:

Instrument(s) Used (model or unit no.): ______________________________

(see Instrument Calibration form dated ______________ for calibration details)

Samplers Name: **Samplers Signature:**

MULTI PARAMETER METER CALIBRATION SHEET

Project Name: ______________________ **Date:** ____________

Task Name: ______________________ **Project Number:** ____________

Equipment Type: Multi Parameter

Manufacturer: ______________________ **Owner of Meter:** ____________

Model Number: ______________________ **Serial Number:** ____________

Date of Last Calibration: ______________

***Be sure to calibrate in the order listed**

Calibration #1: Specific Conductance (SEC; No temperature adjust) **Time:** ____________

Calibration Standard: ______________

Prior Cal Reading: ______________ After Cal Reading: ____________

Calibration #2: pH 7 (adjust for temperature) **Time:** ____________

Calibration Standard: ______________

Prior Cal Reading: ______________ After Cal Reading: ____________

Calibration #3: pH 4 (adjust for temperature) **Time:** ____________

Calibration Standard: ______________

Prior Cal Reading: ______________ After Cal Reading: ____________

Calibration #4: pH 10 (adjust for temperature) **Time:** ____________

Calibration Standard: ______________

Prior Cal Reading: ______________ After Cal Reading: ____________

Calibration #5: ORP (adjust for temperature) **Time:** ____________

Calibration Standard: ______________

Prior Cal Reading: ______________ After Cal Reading: ____________

Calibration #6: DO % **Time:** ____________

Calibration Standard: ______________ True BP* (mm Hg): ____________

Prior Cal Reading: ______________ After Cal Reading: ____________

Misc. Comments: ______________________________________

____

Calibrated by:

*** True BP = corrected BP - [2.5 x (Local Altitude in feet above sea level)/100]**
Corrected BP is corrected to sea level and is typically reported by the weather service.

SINGLE POINT CALIBRATION SHEET (ONE WEEK)

Project Name: ______________________ **Week of:** ______________

Task Name: ______________________ **Project Number:** ______________

Equipment Type: ______________________

Manufacturer: ______________________ **Owner of Meter:** ______________

Model Number: ______________________ **Serial Number:** ______________

Date of Last Calibration: ______________

Calibrated By: ______________

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Calibrated By: ______________

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Calibrated By: ______________

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Calibrated By: ______________

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Calibrated By: ______________

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Misc. Comments: ____

____

Calibrated by:

MULTI-POINT CALIBRATION SHEET

Project Name: ______________________ **Date:** ______________

Task Name: ______________________ **Project Number:** ______________

Equipment Type: ______________________

Manufacturer: ______________________ **Owner of Meter:** ______________

Model Number: ______________________ **Serial Number:** ______________

Date of Last Calibration: ______________

Standard #1

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Standard #2

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Standard #3

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Standard #4

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Standard #5

Calibration Standard: ______________ **Date:** ______________

Instrument Reading: ______________ **Time:** ______________

Misc. Comments: ____

____

Calibrated by:

YSI 9300 and 9500 Photometers

User Manual

Table of Contents

TABLET REAGENT SYSTEM

Direct-Reading Photometer Program Schedule

TABLET REAGENT SYSTEM

Instruction Sheet Number	Reagent System	Parameter	Photometer Program Number
-	-	Transmittance (%)	Phot 0
-	-	Absorbance	Phot1
PHOT.2.	Alkalinity, Total (Alkaphot)	Total Alkalinity	Phot 2
PHOT.37.	Alkalinity M (Alkaphot M)	Alkalinity M	Phot 37 (M)
PHOT.37.	Alkalinity P (Alkaphot P)	Alkalinity P	Phot 38 (P)
PHOT.3.	Aluminum	Aluminum	Phot 3
PHOT.4.	Ammonia	Ammonia Nitrogen	Phot 4
PHOT.5.	Bromine	Bromine – Total	Phot 5
		Bromine – Free	Continuation test* (Phot 6)
PHOT.12.	Calcium Hardness (Calcicol)	Calcium Hardness	Phot 12
PHOT.46.	Chloride (Chloridol)	Chloride	Phot 46
PHOT.7.	Chlorine (DPD)	Chlorine - Free	Phot 7
		Chlorine – Total	Continuation test* (Phot 8)
PHOT.7.1.	Chlorine/Chloramines (DPD)	Chlorine – Free	Phot 71
		Monochloramine	Continuation test* (Phot 72)
		Dichloramine	Continuation test* (Phot 73)
PHOT.8	Chlorine (DPD4)	Total Chlorine	Phot 8
PHOT.74.	Chlorine Dioxide LR	Chlorine Dioxide	Phot 74
PHOT.76.	Chlorine Dioxide HR	Chlorine Dioxide	Phot 76
PHOT.7.3.	Chlorine Dioxide (DPD Glycine Method)	Chlorine Dioxide	Phot 7
PHOT.9.	Chlorine HR	Chlorine	Phot 9
PHOT.55.	Chromium (Chromicol)	Hexavalent	Phot 55
	Chromium III – supplement to YPM281 above	Total and Trivalent	Continuation test* (Phot 100)
PHOT.47.	Color	Color	Phot 47
PHOT.10.	Copper (Coppercol)	Copper – Free	Phot 10
		Copper – Total	Continuation test* (Phot 11)
PHOT.13.	Cyanuric Acid	Cyanuric Acid	Phot 13
PHOT.49.	Dissolved Oxygen (0.0 – 0.8 vials)	Dissolved Oxygen	Phot 49
PHOT.50.	Dissolved Oxygen (0.0 – 2.0 vials)	Dissolved Oxygen	Phot 50
PHOT.14.	Fluoride	Fluoride	Phot 14
PHOT.15.	Hardness, Total (Hardicol)	Total Hardness	Phot 15
PHOT.41.	Hydrazine	Hydrazine	Phot 41
PHOT.16.	Hydrogen Peroxide LR	Hydrogen Peroxide	Phot 16
PHOT.17.	Hydrogen Peroxide HR	Hydrogen Peroxide	Phot 17
PHOT.18.	Iron LR	Iron	Phot 18
PHOT.39.	Iron MR	Iron	Phot 39
PHOT.19.	Iron HR	Iron	Phot 19
PHOT.21.	Magnesium (Magnecol)	Magnesium	Phot 21
PHOT.20.	Manganese	Manganese	Phot 20
PHOT.42.	Molybdate LR	Molybdate	Phot 42
PHOT.22.	Molybdate HR	Molybdate	Phot 22
PHOT.53.	Nickel (Nickeltest)	Nickel	Phot 53

Instruction Sheet Number	Reagent System	Parameter	Photometer Program Number
PHOT.23.	Nitrate (Nitratest)	Nitrate Nitrogen	Phot 23
PHOT.24.	Nitrite (Nitricol)	Nitrite Nitrogen	Phot 24
PHOT.43.	Nitrite (Nitriphot)	Sodium Nitrite	Phot 43
PHOT.44.	Organophosphonate (OP)	Org-Pho (+Phos)	Phot 44
		Organophosphonate	Continuation test* (Phot 45)
PHOT.25.	Ozone	Ozone (+Chlor)	Phot 25
		Ozone	Continuation test* (Phot 26)
PHOT.27.	pH Value	pH – Phenol Red	Phot 27
PHOT.54.	Phenol (Phenoltest)	Phenol	Phot 54
PHOT.52.	PHMB (PHMB-PHOT)	PHMB	Phot 52
PHOT.28.	Phosphate LR	Phosphate	Phot 28
PHOT.29.	Phosphate HR	Phosphate	Phot 29
PHOT.30.	Potassium	Potassium	Phot 30
PHOT.31.	Silica LR	Silica	Phot 31
PHOT.56.	Silica HR	Silica	Phot 56
PHOT.32.	Sulfate	Sulfate	Phot 32
PHOT.33.	Sulfide	Sulfide	Phot 33
PHOT.34.	Sulfite (Sulfitest)	Sulfite	Phot 34
PHOT.48.	Turbidity	Turbidity	Phot 48
PHOT.35.	Zinc	Zinc (+ Copper)	Phot 35
		Zinc	Continuation test* (Phot 36)

*Continuation tests cannot be accessed directly

PHOTOMETER TEST INSTRUCTIONS

ALKALINITY M and P (ALKAPHOT M and P)

Photometer Method

AUTOMATIC WAVELENGTH SELECTION

$0 - 500$ mg/l $CaCO_3$

TESTS FOR ALKALINITY M and P IN BOILER WATER AND OTHER INDUSTRIAL WATERS

The Alkalinity of water is caused by the presence of alkaline substances such as hydroxides, carbonates, bicarbonates and, to a lesser extent, silicates and phosphates. Quantitatively alkalinity is the capacity of the water to react with acid to a specified pH end point. The value obtained will depend on the pH indicator used. Two measures of alkalinity are conventionally applied - Alkaphot M (Alkalinity to methyl orange) and Alkaphot P (Alkalinity to phenolphthalein).

Alkalinity is an important test parameter in a number of industrial water uses, notably in boiler water treatment. Boilers and steam raising plant are normally operated under conditions of high alkalinity in order to minimise corrosion and the monitoring of alkalinity is an important control test.

The YSI Alkaphot M and Alkaphot P tests provide a simple means of checking Alkalinity M and Alkalinity P levels over the range 0 - 500 mg/l $CaCO_3$. The tests are particularly suited to boiler and industrial waters. The alkalinities specifically due to carbonates, bicarbonates and hydroxides can be calculated from the various data obtained.

Method

The YSI Alkaphot M and Alkaphot P tests are both based on unique colorimetric methods. These methods offer considerable advantages over the titrimetric methods traditionally used for measuring these parameters.

The tests are each based on the use of a single tablet reagent containing a precisely standardised amount of acid combined with a color indicator. The tests are simply carried out by adding the appropriate tablet to a sample of the water under test. Over the alkalinity range of each test a distinctive series of colors is produced - from yellow through green to blue in the case of the Alkaphot M test and from colorless to purple in the case of the Alkaphot P test.

The color produced in each of the tests is indicative of the alkalinity and is measured using a YSI Photometer.

Reagents and Equipment

YSI Alkaphot M Tablets
YSI Alkaphot P Tablets
YSI 9300 or 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

Test Procedure - Alkaphot M

1. Filter sample if necessary to obtain a clear solution.
2. Fill the test tube to the 10 ml mark with sample.
3. Add one Alkaphot M tablet, crush and mix. Ensure all particles are dissolved.
4. Select Phot 37 on the photometer.
5. Take photometer reading in the usual manner.
6. The result is displayed as mg/l $CaCO_3$.

Test Procedure - Alkalinity P

1. Filter sample if necessary to obtain a clear solution.
2. Fill the test tube to the 10 ml mark with sample.
3. Add one Alkaphot P tablet, crush and mix to dissolve.
4. Stand two minutes to allow complete color development.
5. Select Phot 38 on the photometer.
6. Take photometer reading immediately in the usual manner.
7. The result is displayed as mg/l $CaCO_3$.

Alkalinity Relationships

From the results obtained from the foregoing procedures it is possible to classify the sample into the three main chemical forms of alkalinity present in most waters, namely hydroxides, carbonates and bicarbonates. This calculated relationship assumes the absence of other weak forms of alkalinity and also assumes that hydroxides and bicarbonates are not compatible in the same sample. The chemical forms of alkalinity, expressed as mg/l $CaCO_3$ are calculated by the following equations:-

a) If Alkalinity P = 0
Then Bicarbonate = M
Carbonate = 0
Hydroxide = 0

b) If Alkalinity P > 0 and M > 2P
Then Bicarbonate = M - 2P
Carbonate = 2P
Hydroxide = 0

c) If Alkalinity P > 0 and M < 2P
Then Bicarbonate = 0
Carbonate = 2M - 2P
Hydroxide = 2P – M

Where P and M are the results of the Alkaphot P and Alkaphot M tests respectively.

NOTE

The expression of alkalinity results sometimes causes confusion. It is normal practice to express the result as mg/l $CaCO_3$ (calcium carbonate). This is merely a convention to allow the comparison of different results and does not necessarily indicate that the alkalinity is present in the water in this form. The different chemical forms of alkalinity have been referred to in the test instructions.

PHOTOMETER TEST INSTRUCTIONS

ZINC

TEST FOR ZINC IN NATURAL AND TREATED WATERS

Photometer Method

AUTOMATIC WAVELENGTH SELECTION

0 – 4.0 mg/l

Zinc compounds are used as corrosion inhibitors in industrial cooling water systems and similar applications. Control of the zinc level is an important aspect of corrosion control in such systems. Zinc and zinc containing alloys are widely used in industry and zinc salts are commonly found in industrial effluents.

The YSI Zinc test provides a simple means of testing zinc levels over the range 0 - 4 mg/l and is suitable for testing cooling waters and industrial effluents, and for the monitoring of natural and drinking waters.

Method

Zinc reacts with 5-(o-carboxyphenyl)-1-(2-hydroxy-5-sulphophenyl)-3-phenyl-formazan (Zincon) in alkaline solution to give an intense blue color. The reagent itself is orange in solution. At different zinc levels a distinctive color range from orange through purple to blue is produced. In the YSI Zinc test a tablet reagent containing both Zincon and an alkaline buffer is used for maximum convenience. The test is simply carried out by adding a tablet to a sample of the water. Samples containing high chlorine residuals are pre-treated with a special dechlorinating tablet to prevent bleaching of the test colors.

The color produced in the test is indicative of the zinc concentration and is measured using a YSI Photometer.

Copper reacts in a similar manner to zinc and a correction procedure using EDTA is applied to those samples which contain both zinc and copper. EDTA destroys the color complex formed with zinc.

Reagents and Equipment

YSI Zinc Tablets
YSI Zinc-Dechlor Tablets
YSI EDTA Tablets
YSI 9300 or 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

SEPARATION OF RESIDUALS

The photometer is programmed for both zinc and the copper correction procedure. Use program **Phot 35** Zinc (+ Copper), then select the 'Follow On' option on screen to continue test for program **Phot 36** Corrected Zinc. The corrected zinc value is calculated automatically.

Test Procedure

1. Fill test tube to the 10 ml mark.
2. **IN THE CASE OF CHLORINE CONTAINING SAMPLE ONLY** :-
   Add one Zinc-Dechlor tablet, crush and mix to dissolve.
3. Add one Zinc tablet, crush and mix to dissolve.
4. Allow the sample to stand for five minutes then mix again to ensure complete dissolution of the indicator.
5. Select Phot 35 on photometer.
6. Take photometer reading in usual manner (see photometer instructions). The result is displayed as mg/l Zn.
7. **FOR COPPER CONTAINING SAMPLES ONLY** :-
   Continue the test on the same test portion. Select the 'Follow On' option on screen to continue the test program.
8. Add one EDTA tablet, crush and mix to dissolve.
9. Take photometer reading in usual manner.
10. The photometer displays the corrected zinc concentration as mg/l Zn.

PHOT.33.AUTO

PHOTOMETER TEST INSTRUCTIONS

SULFIDE

TEST FOR SULFIDE IN NATURAL AND WASTE WATERS

Photometer Method

AUTOMATIC WAVELENGTH SELECTION

0 – 0.5 mg/l

Natural waters containing dissolved hydrogen sulfide and other sulfides are found in certain parts of the world, particularly in areas having hot springs. Sulfides are constituents of many industrial wastes such as those from tanneries, gas plants and chemical works. Sulfides can be toxic to fish and aquatic life; and their presence in water supplies gives rise to undesirable tastes and odours.

The YSI Sulfide Test provides a simple method of measuring total available sulphide over the range 0 - 0.5 mg/l and is particularly applicable to natural and drinking waters. Higher levels, such as those found in effluents and waste waters, can be determined by diluting the sample.

Method

This simplified method for the determination of sulphide is based on a reagent containing diethyl-p-phenylene diamine (DPD) and potassium dichromate. Sulfide reacts with this reagent in acid solution to produce a blue colored complex. In the absence of sulphide the reagent produces a pink color. Chlorine, and other oxidizing agents which normally react with DPD, do not interfere with the test. The reagents are provided in the form of two tablets and the test is simply carried out by adding one of each tablet to a sample of the water.

The color produced is indicative of the sulphide concentration and is measured using a YSI Photometer.

Reagents and Equipment

YSI Sulfide No 1 Tablets
YSI Sulfide No 2 Tablets
YSI 9300 or 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

Sample Collection

To prevent loss of sulphide collect the sample carefully with a minimum of agitation or aeration. Test the sample as soon as possible after collection.

Test Procedure

1 Fill test tube with sample to the 10 ml mark.

2 Add one Sulphide No 1 tablet and one Sulfide No 2 tablet. Crush and mix gently to dissolve the tablets. Gentle mixing is essential to avoid loss of sulphide.

3 Stand for 10 minutes to allow full color development.

4 Select Phot 33 on photometer.

5 Take photometer reading in usual manner (see photometer instructions).

6 The result is displayed as mg/l S.

To convert from mg/l S to mg/l H_2S - multiply result by 1.06

PHOTOMETER TEST INSTRUCTIONS

IRON LR

TEST FOR LOW LEVELS OF IRON IN NATURAL AND TREATED WATER

Photometer Method

AUTOMATIC WAVELENGTH SELECTION

0 – 1.0 mg/l

Iron occurs widely in nature and is found in many natural and treated waters. Iron is an objectionable constituent in both domestic and industrial water supplies. The presence of iron affects the taste of beverages and causes unsightly staining of laundered clothes, plumbing fittings, swimming pool surfaces and the like. The formation of insoluble iron deposits is troublesome in many industrial applications and in agricultural water uses such as drip feed irrigation. In industry iron salts occur through corrosion of plant and equipment, and from industrial processes.

Iron is therefore an important test for the monitoring of natural and drinking waters, for corrosion control in industry and for the checking of effluents and waste waters. The YSI Iron LR test provides a simple test for the determination of low levels of iron in water over the range 0 - 1 mg/l Fe. The test responds to both ferrous and ferric iron and thus gives a measure of the total iron content of the water.

Method

The YSI Iron LR test is based on a single tablet reagent containing 3-(2-Pyridyl)-5, 6-bis(4-phenyl-sulphonic acid)-1, 2, 4-triazine (PPST) formulated with a decomplexing/reducing agent in an acid buffer. The test is simply carried out by adding a tablet to a sample of the water under test. The decomplexing/ reducing agent breaks down weakly complexed forms of iron, and converts the iron from the ferric to the ferrous form. The ferrous iron reacts with PPST to form a pink coloration.

The intensity of the color produced is proportional to the iron concentration and is measured using a YSI Photometer.

Reagents and Equipment

YSI Iron LR Tablets
YSI 9300 or 9500 Photometer
Round Test Tubes 10 ml glass (PT 595)

Test Procedure

1 Fill the test tube with sample to the 10 ml mark.
2 Add one Iron LR tablet, crush and mix to dissolve.
3 Stand for one minute to allow full color development.
4 Select Phot 18 on photometer.
5 Take photometer reading in usual manner (see photometer instructions).
6 The result is displayed as mg/l Fe.

Iron Complexes

The test color development will normally be complete within one minute. Continued color development after this time is indicative of more strongly bound iron complexes in the water. In such cases the test solution should be stood for a longer period, say 10 - 15 minutes, until color development is complete.

In certain industrial applications strong complexing agents are added to act as corrosion inhibitors. Moreover, some samples may contain precipitated iron complexes or particles of metallic iron. These samples will require pre-treatment by a standard laboratory procedure if it is required to determine the total iron content. The usual method of pre-treatment is acidification-with or without boiling, depending, on the nature of the sample.

To use the YSI Iron LR test after such pre-treatment procedures, add the Iron LR tablet to the acidified sample, adjust to pH 3.5 - 4.0 using ammonia or sodium hydroxide, then take the photometer reading in the normal manner.

PHOTOMETER TEST INSTRUCTIONS

IRON HR

Photometer Method

AUTOMATIC WAVELENGTH SELECTION

0 – 10 mg/l

TEST FOR HIGH LEVELS OF IRON IN NATURAL AND TREATED WATER

Iron occurs widely in nature and is found in many natural and treated waters. Iron is an objectionable constituent in both domestic and industrial water supplies. The presence of iron affects the taste of beverages and causes unsightly staining of laundered clothes, plumbing fittings, swimming pool surfaces and the like. The formation of insoluble iron deposits is troublesome in many industrial applications and in agricultural water uses such as drip feed irrigation. In industry iron salts occur through corrosion of plant and equipment, and from industrial processes.

Iron is therefore an important test for the monitoring of natural and drinking waters, for corrosion control in industry and for the checking of effluents and waste waters. The YSI Iron HR test provides a simple test for the determination of high levels of iron in water over the range 0 - 10 mg/l Fe. The test responds to both ferrous and ferric iron and thus gives a measure of the total iron content of the water.

Method

The YSI Iron HR test is based on a single tablet reagent containing an alkaline thioglycollate. The test is carried out simply by adding a tablet to a sample of the water under test. The thioglycollate reduces ferric iron to ferrous iron and this, together with any ferrous iron already present in the sample, reacts to give a pink coloration.

The intensity of the color produced is proportional to the iron concentration and is measured using a YSI Photometer.

Reagents and Equipment

YSI Iron HR Tablets
YSI 9300 or 9500 Photometer
Round Test Tubes, 10 ml glass (PT 595)

Test Procedure

1 Fill test tube with sample to the 10 ml mark.
2 Add one Iron HR tablet, crush and mix to dissolve.
3 Stand for one minute to allow full color development.
4 Select Phot 19 on photometer.
5 Take photometer reading in usual manner (see photometer instructions).
6 The result is displayed as mg/l Fe.

Iron Complexes

The test color development will normally be completed within one minute. Continued color development after this time is indicative of more strongly bound iron complexes in the water. In such cases the test solution should be stood for a longer period, say 10 - 15 minutes, until color development is complete.

In certain industrial applications strong complexing agents are added to act as corrosion inhibitors. Moreover some samples may contain precipitated iron complexes or particles of metallic iron. These samples will require pre-treatment by a standard laboratory procedure if it is required to determine the total iron content. The usual method of pre-treatment is acidification - with or without boiling, depending on the nature of the sample.

To use the YSI Iron HR test after such pre-treatment procedures, add the Iron HR tablet to the acidified sample, adjust to pH 6.0 - 9.0 using ammonia or sodium hydroxide, then take the photometer reading in the normal manner.

a xylem brand Technical Performance Specification for YSI Photometers

TEST	WORKING RANGE mg/l	DETECTION LIMIT mg/l	TOLERANCE (± mg/l @ mg/l)
Alkalinity, Total (Alkaphot)	0 - 500	10	± 7 @ 200
Alkalinity M (Alkaphot M)	0 - 500	10	± 5 @ 200
Alkalinity P (Alkaphot P)	0 - 500	10	± 5 @ 200
Aluminium	0 - 0.5	0.02	± 0.02 @ 0.20
Ammonia	0 - 2.0 (N)	0.01	± 0.01 @ 0.25
Ammonia Tubetests®	0 - 12 (N)	0.15	± 0.1 @ 1.0
Ammonia Tubetests®	0 - 50 (N)	0.7	± 0.3 @ 5.0
Boron	0 - 2.5	0.05	± 0.05 @ 1.00
Bromine	0 - 10.0	0.04	± 0.05 @ 1.00
Calcium Hardness (Calcicol)	0 - 500	5	± 5 @ 100
Chloride (Chloridol)	0 - 50	0.5	± 0.5 @ 10.0
Chlorine DPD	0 - 5.0	0.01	± 0.03 @ 1.00
Chlorine Dioxide (DPD) (ClO_2)	0 - 10	0.02	± 0.03 @ 1.00
Chlorine HR	0 - 250	1	± 2 @ 50
Chromium (Chromicol)	0 - 1.0	0.02	± 0.02 @ 0.3
COD	0 - 150	3	± 6 @ 135
	0 - 400	5	± 10 @ 360
	0 - 2000	10	± 60 @ 1790
	0 - 20,000	100	± 600 @ 17,900
Copper (Coppercol)	0 - 5.0	0.03	± 0.04 @ 1.00
Cyanuric Acid	0 - 200	2	± 10 @ 100
Fluoride	0 - 1.5	0.1	± 0.05 @ 1.00
Hardness (Hardicol)	0 - 500	5	± 5 @ 100
Hydrogen Peroxide LR	0 - 2.0	0.02	± 0.01 @ 0.50
Hydrogen Peroxide HR	0 - 100	1	± 1 @ 25
Iron LR	0 - 1.0	0.01	± 0.01 @ 0.20
Iron HR	0 - 10	0.05	± 0.25 @ 2.0
Iron MR	0 - 5.0	0.02	± 0.05 @ 1.00

YSI
1725 Brannum Lane
Yellow Springs, OH 45387
Tel: +1-937-767-7241, 800-765-4974
environmental@ysi.com
www.ysi.com

TEST	WORKING RANGE mg/l	DETECTION LIMIT mg/l	TOLERANCE (± mg/l @ mg/l)
Magnesium (Magnecol)	0 - 100	2	± 1 @ 20
Manganese	0 - 0.03	0	± 0.002 @ 0.010
Molybdate LR	0 - 15	0.2	± 0.15 @ 2.0
Molybdate HR	0 - 100	0.5	± 1 @ 25
Nickel (Nickeltest)	0 - 10	0.12	± 0.10 @ 2.0
Nitrate (Nitratest)	0 - 20 (N)	0.2	± 1.0 @ 10.0
Nitrate Tubetests®	0 - 30 (N)	0.3	± 0.4 @ 10
Nitrite (Nitricol)	0 - 0.5 (N)	0	± 0.002 @ 0.100
Nitrite (Nitriphot)	0 - 1500	10	+/- 5 @ 100
Organophosphonate	0 - 20	0.2	+/- 0.25 @ 5.00
Ozone	0 - 2.0	0.01	± 0.02 @ 0.50
pH (Phenol Red)	6.8 - 8.4	6.80 - 8.40	± 0.05 @ 7.00
Phenol	0 - 5.0	0.07	± 0.05 @ 1.0
PHMB	0 - 100	2	± 2 @ 50
Phosphate LR	0 - 4.0	0.03	± 0.03 @ 1.00
Phosphate HR	0 - 100	1	± 3 @ 50
Potassium	0 - 12	0.5	± 0.5 @ 5.0
Silica LR	0 - 4.0	0.02	± 0.04 @ 1.0
Silica HR	0 - 150	0.5	± 2.0 @ 50.0
Sulphate	0 - 200	5	± 4 @ 50
Sulphide	0 - 0.5	0.01	± 0.01 @ 0.10
Sulphite (Sulphitest)	0 - 500	5	± 5 @ 100
Zinc	0 - 4.0	0.02	± 0.03 @ 1.00

Working Range - This is the overall working range of the reagent system. This information should be read in conjunction with the measuring range of the equipment or test kit being used which may be more restricted.

Detection Limit - This is the lowest limit which can be reliably detected using the reagent system.

Tolerance - This is the manufacturing tolerance against which the reagent system is quality controlled by testing against standard solutions.

These specifications are based on test reagents being used in the manner described in our published test instructions. Specifications are subject to change without notice.

4.0 – EQUIPMENT DECONTAMINATION

Purpose and Scope: The purpose of this document is to describe procedures for equipment decontamination. It describes decontamination methods and provides specific procedures for decontaminating drilling and excavation equipment, submersible pumps, decontamination for the collection of equipment blanks, and water level meters.

Equipment:

Steam Cleaner
5-gallon buckets with lids
Bucket labels
Brushes
Distilled water
Potable water
Spray bottles
Paper towels
Liquinox® or other Non-Phosphate Cleaning Solution (not Alconox®)
10 mil visqueen

Documentation: Daily Field Record (DFR)

4.1 DECONTAMINATION PROCEDURES

Decontamination procedures described in this section are applicable to non-dedicated, non-disposable sampling equipment. The following subsections describe the methods of decontamination and procedures for decontaminating specific types of sampling equipment.

4.1.1 Decontamination Methods

All sampling equipment must be decontaminated after it arrives onto the site and before each sampling operation. This includes subcontractor equipment. Decontamination onsite will use one of the methods below:

- Three-Step System
- Steam Cleaner

The procedures for decontamination using the three-step system or steam cleaner are described in the following subsections. The exception to using the three-step system or a steam cleaner for decontamination is when cleaning a water level meter. This is described in Section 4.1.2.4 of this SOP.

4.1.1.1 Three Step System

The three step decontamination system consists of washing the sampling equipment: (1) in soapy water using a non-phosphate (Liquinox®) solution, (2) rinsing with potable water and (3) rinsing again with distilled water. The Liquinox® solution will be mixed in accordance with the manufacturer's recommendations. Equipment will be washed in a row of three containers. Depending on the equipment to be decontaminated, spray bottles containing the applicable solutions may be used. Hard bristle bottle brushes may be used to remove mud and debris prior to the three step system with an optional fourth container. Sample equipment should be allowed to drain dry after the final distilled water rise. Decontamination water will be disposed of according to procedures described in SOP 5.0 – Investigation Derived Waste Disposal.

4.1.1.2 Steam Cleaner

The steam cleaner will be supplied by a subcontractor and operated according to the manufacturer's recommendations. It will be capable of generating a working pressure of approximately 1,500 to 2,000 pounds per square inch (psi), a discharge rate of 3 to 5 gallons per minute (gpm), and an operating temperature of approximately 130 to 150 degrees Fahrenheit (˚F).

The steam cleaner will be used within a decontamination station designed to capture all of the water. The decontamination station may be mounted on a portable trailer or constructed onsite and will be supplied or built by a subcontractor. If constructed, the on-site decontamination area will be lined and bermed with two layers of 10 mil visqueen to contain rinsate from steam cleaning operations. If appropriate, the decontamination area will be designed to allow heavy equipment (backhoe, drilling rig, and support vehicles) to drive onto the visqueen. During operation of the steam cleaner, the field engineer or geologist will establish and maintain an exclusion zone. Decontamination water will be retained and disposed according to procedures described in SOP 5.0 – Investigation Derived Waste Disposal.

4.1.2 Sampling Equipment

The following subsections provide specific details for decontaminating drilling and excavation equipment, submersible pumps, equipment blanks, and water level meters.

4.1.2.1 Drilling and Excavation Equipment

Drilling and excavating equipment, including backhoe buckets, drill bits, casing, augers, and tools or other equipment that have come in contact with potentially impacted soils or water will be cleaned between each location, as appropriate. After completion of each boring, drill casing or augers, drill bits and drill rods will be transported by truck to the steam cleaning area. Drill casing from the monitoring well drilling procedures will be lifted from the support truck and cleaned within the decontamination station. Heavy tooling with edges that can damage the decontamination area will be placed on lumber in the decontamination area for cleaning. Rinsate collected in the decontamination area will be retained and disposed according to SOP 5.0 – Investigation Derived Waste Disposal.

4.1.2.2 Submersible and Bladder Pumps

If a non-dedicated submersible pump is used, it will be cleaned prior to use and between sampling locations using the three-step system. First, the pump intake device will be submersed into non-phosphate cleaning solution (Liquinox®) and recycled within a bucket for at least 30 seconds. Second, the pump will be submersed into a bucket containing potable water and recycled within the container for at least 30 seconds. The second step should be performed sufficiently rinse the suds from the pump. The third step involves rinsing the pump within a bucket filled with distilled water using the same method as Steps 1 and 2.

If a non-dedicated bladder pump is used, it will first be disassembled and decontaminated using the three-step system. If so equipped, the disposable bladder will be removed and replaced with a new bladder. The used bladder will be disposed using project procedures for disposing solid waste. Then, the bladder pump will be assembled and rinsed with distilled water.

4.1.2.3 Equipment Blanks

As appropriate, equipment blanks may be collected after decontamination of the sampling equipment during sampling activities to provide an additional check on possible sources of contamination related to field sampling instruments. Equipment blanks are prepared using distilled or deioniezed water that is poured through or over the sampling device. The collected rinse water is then transferred to the appropriate sampling container(s) and handled in a manner similar to the associated field samples as described in SOP 1.0 – Field Documentation and Sample Handling.

4.1.2.4 Water Level Meters

Water level meters will be decontaminated using a two-step system. This system consists of a spray bottle containing non-phosphate detergent (Liquinox®) mixed with water and a spray bottle containing distilled water. The Liquinox® solution will be mixed in accordance with the manufacturer's recommendations. The soapy water will be sprayed on the portion of the water level meter that was submerged and then rinsed by spraying distilled water until all suds are removed. The submerged portion of the water level meter will then be wiped down with a paper towel. If residual dirt or other contaminants remain on the water level meter after being rinsed, the above steps will be repeated using a brush to remove the remaining debris. Rinse water from the above procedures will be captured in a bucket or other appropriate container, labeled, and disposed in accordance with procedures described in SOP 5.0 – Investigation Derived Waste Disposal.

4.2 Revision Log

Revision #	Author	Description of Change (Section #)	Date	Reviewer
01	ARC	General formatting and editing Section 4.1.2.3 – modified equipment blank sampling procedures	6/4/13	LL 6/6/13

5.0 – INVESTIGATION DERIVED WASTE DISPOSAL

Purpose and Scope: The purpose of this document is to present procedures for containment and disposal of investigation derived waste such as soil, water, and materials.

Equipment:

Buckets, containers with covers for soil and water
(e.g., 55-gallon drums, 20-yard roll-off bins, Baker Tanks™)
Waste disposal labels
Appropriate sample containers and sampling equipment
Miscellaneous tools
Safety Equipment

Documentation:

Daily Field Record (DFR)
Waste Tracking Log (attached)
Maps/plot plan
Camera

The procedures below are to be followed for investigation derived waste consisting of water, soil, materials such as personal protective equipment (PPE) or disposable sampling equipment, and liquid waste such as waste calibration solution and field test reagent waste. Investigation derived groundwater will be generated from well development and purging activities. Investigation derived waste water will be generated during decontamination activities. Investigation derived soil will be generated from soil borings.

All containers containing waste will be kept closed and sealed at all times unless actively adding waste. Each container must have a visible and legible label present. Labels will be constructed of weather-resistant vinyl and waterproof ink markers will be used to add information in the field. All empty containers must have a label that indicates that the container is empty. Prior to filling any waste containers, the sampler will replace the empty label with a label that describes the source of the waste (well or boring ID), the contents (soil or water), date accumulation started, date accumulation finished, and a name and contact information of the generator. The location of the waste generated will be documented on a waste tracking log (attached).

5.1 WATER DISPOSAL PROCEDURES

Groundwater produced during the well development and purging activities will be discharged to the ground surface near the well for evaporation and infiltration or into one of the storage ponds. Water will be discharged in a manner that prevents erosion, pooling of water, or migration to a surface water body and will be performed in accordance with the HSSE Program document and the TSHASP. Measures to prevent erosion or migration may consist of installing silt fencing down slope of discharge areas or transporting and land applying water in a more appropriate location. If surface discharge is not practicable or allowed, water may be containerized (e.g. in a pipe, hose, or drum) and transported to an onsite treatment system, or may be transported off-site for appropriate disposal.

Waste water produced from decontamination activities will be disposed in the same manner as described above. This includes Liquinox® (a non-phosphate detergent) that is mixed with water using the manufacturer's recommendations. Alconox® or other detergents containing phosphates will not be used on site. If other cleaning agents are used during decontamination, the field engineer or geologist will contact the Project Manager for guidance on the proper disposal procedure.

It is not anticipated that investigation-derived waste water will be transported off site.

5.2 SOIL DISPOSAL PROCEDURES

It is anticipated that most soil investigations will be performed in areas that have unconsolidated material at the surface that was left behind from previous site activities (i.e., mining, construction). Any soil or mud developed during the drilling or excavation activities are expected to have similar characteristics as the disturbed material that exists in the vicinity of the investigation. Therefore, if disturbed material already exists at the surface, any soil or mud developed during the investigation will be spread evenly in the immediate vicinity. The material will be spread in a manner that has a low profile as to prevent windblown dust from occurring. These soil disposal activities will be performed in a manner that prevents migration to a surface water body and in accordance with the HSSE Program document and the TSHASP.

If soil and mud produced during the investigation is suspected to contain other contaminants (e.g., petroleum odors, ethanol odor), the field Engineer or Geologist will contact the Project Manager for guidance. Exceptions to the above soil disposal procedures will be addressed on a case-by-case basis.

5.3 MATERIAL DISPOSAL PROCEDURES

Used PPE, sampling devices that contact with source water, and all other disposable equipment, including items such as rope and non-hazardous well construction materials will be disposed in the onsite municipal solid waste trash receptacle. The exception is for the disposal of equipment that has come in contact with contaminants that are suspected to be non-native to the area or those that are known to be hazardous (e.g., ethanol, diesel fuel, etc.). If this situation exists, the field engineer or geologist will contact the Project Manager for guidance.

5.4 LIQUID WASTE

Liquid investigation derived waste generated at the site will include waste calibration solutions (pH buffers, specific electrical conductance, oxidation reduction potential, turbidity) and field test reagent waste. Liquid waste will be stored for disposal in containers that are sealed and labeled. These containers will be stored onsite on secondary containment and later transported to an appropriate offsite disposal facility.

Liquid waste will be segregated in containers based on chemical compatibility. The Health and Safety Manager is responsible for reviewing material safety data sheets, evaluating chemical compatibility of liquid wastes and determining storage options for liquid wastes generated.

5.5 OFFSITE FACILITY DISPOSAL PROCEDURES

Offsite disposal of investigation derived waste is not expected. However in the event that it is needed, the location and quantity of the waste that is generated will be documented on a map and Waste Tracking Log (attached).

Offsite disposal of waste will be performed in accordance with appropriate Federal, State, and local regulations. A sample of the waste to be disposed at an offsite facility will be collected and submitted to a laboratory for analysis. Analytical results of the sample will then be sent to the disposal facility where a waste profile will be generated. The profile will be reviewed and signed by a designated Atlantic Richfield representative. The U.S. EPA will then be notified of all types and quantities of waste prior to its shipment off site.

Upon approval of the waste profile, an appropriate manifest (Hazardous or Non-Hazardous) will be completed. All waste manifests will be reviewed and signed by a designated Atlantic Richfield representative. The truck driver transporting the waste will also sign and keep the manifest in his presence at all times while transporting the container to the disposal facility. The truck driver will be responsible for adhering to all Department of Transport (DOT) rules and regulations for the transport of waste on public roads.

5.6 REVISION LOG

Revision #	Author	Description of Change (#)	Date	Reviewer
01	ARC	Section 5.3 – revised text to say that PPE, disposable sampling equipment will be disposed in municipal solid waste trash receptacle. Section 5.4 – added section to describe handling of liquid waste.	6/4/2013	LL 6/6/13

ATTACHMENT

- Waste Tracking Log

Waste Tracking Log
Rico-Argentine Mine Site - Rico Tunnels
Operable Unit OU01
Rico, Colorado

Date	Waste Type and Volume	Source Location	Container Type and Volume	Number of Containers	Storage Location

6.0 – STREAM FLOW MEASUREMENT AND SURFACE WATER SAMPLING

Purpose and Scope: The purpose of this document is to provide a general outline for developing site specific procedures for collection of representative surface water samples measurements in small streams, small rivers or ponds and lakes.

Equipment:

Surface Water Sample Collection Devices:
- Dip sampler;
- Discrete depth sampler and associated equipment;
- Peristaltic pump, power supply and associated equipment;

Directional Compass;
25-foot Steel Tape and 100-foot Flexible Tape Measure;
Survey stakes, flagging, hammer;
Marking Buoys, pre-stretched line and anchors;
Boat or Raft (deep River or Pond/Lake Sampling);
- Appropriate Line;
- USCG Approved Type III Life Vests;

Vertical Staff Gauge;
3-inch, schedule 40 PVC Pipe, length to be determined
Electronic Depth Gauge;
Volumetric Flow Measuring Structure (Flume)
Sample containers (cleaned and provided by the laboratory);
Ice chests and blue or double bagged ice;
Tarps;
Miscellaneous tools;
Safety Equipment,
Hand-Held Global Positioning System (GPS) device; and
Hip boots and Knee-high water tight boots.

Documentation:

Daily Field Record (DFR);
Maps;
Digital Camera and Photo Log;
Sample Control Log;
Atlantic Richfield Chain-of-Custody (COC) form or laboratory equivalent;
Multiparameter Calibration Sheet (or other means to document instrument calibration);
Single Point Calibration Sheet;
General Water Sampling Form; and
Stream Flow (Discharge) Measurement Form (attached).

6.1 STREAM FLOW MEASUREMENT

Small stream and river volumetric flow can be calculated with measurements of the stream cross-sectional area and the velocity of flow through that area using the following formula.

$$Q = V \times A$$

Where,

Q = Discharge (in cubic feet per second)

V = Velocity (in feet per second)

A = Area (in square feet)

The area of the cross-section through which water is flowing will be determined by one or more techniques based on the overall general size of the stream (width and depth) and water velocity. A staff gauge (graduated into feet and tenths of feet (meters and centimeters) can be used to directly measure depths of shallow streams and rivers at select points perpendicular to the stream flow. If the bottom profile of the stream or river is undulating or complicated in some manner, the sum of the volumetric flows of the individual areas making up the cross-section can determine the overall volumetric flow rate. This will require calculating the individual areas and determination of corresponding velocities in those areas. For relatively simple geometries, a simple depth measurement and velocity determination can be directly made. For complicated geometries and deep water (greater than approximately 2.5 feet) multiple velocity readings, using one of a number of velocity specific and calibrated electronic or magnetic flow meters will be required.

An alternative method for directly reading stream or river volumetric flows, at locations that require repeated sampling, may be to install a permanent Weir or Flume that can be used to channel flow and read volumetric flows directly. If this method is utilized, it will require plans and specifications for the design and construction of the structure.

The proper collection of representative surface water samples will also be dependent on the geometry and depths of the surface water to be sampled and the contaminant of concern. Surface water can be sampled through direct filling of contaminant specific sample containers or through collection of the sample in a pre-defined sample collection device where the sample is then transferred to the sample container. Generally, sampling of surface water from ponds and lakes do not require volumetric flows but will require knowledge of the total depth of the pond or lake and a predetermined knowledge of the depths from which samples are to be collected.

The choice of the proper location to collect a surface water sample, the method to measure areas and velocities and the proper choice of the materials of construction and type of flow meter and sample collection device is site and contaminant-specific and shall be defined in the work plans.

All work performed determining areas, velocities and collection of representative samples should be thoroughly documented on a DFR using diagrams. Photographs and a photo log will also be used to document the methods used for measuring flow.

6.1.1 Choosing a Transect Location

Stream flow measurements are performed along a transect of the stream. The transect location should include an area of moving water that can be waded and in an area of channelized flow. Hip boots or Knee-high water tight boots will be used for wading in streams. The transect location should be chosen based on a variety of general criteria ranging from point-source outfalls of concern, stream morphology, accessibility, safety concerns, and the location of pre-established sample locations. Once chosen, a transect location should be documented to provide a basis for repetition and comparison with previous or future sample events.

Stream specific criteria for selecting a transect location include looking for particular characteristics such as:

- a well defined and stable stream bank;
- few obstructions in the channel; and
- no eddies or still water.

Conversely, turbulent water should also be avoided, if possible. The stream should be free flowing and unrestricted by obstructions upstream or downstream, which might cause flow diversion or flow backup. A smooth streambed profile, one of relatively consistent depth across its width, is optimal. The depth of the stream must be adequate for the determination of a flow velocity and subsequent collection of the surface water sample without disturbing the stream bottom sediment.

For purposes of reproducibility, any likely movable objects within the stream bed, which may interfere with the reproducibility with subsequent sample collection events should be removed, if possible and allowable. Removal of channel obstructions, (i.e., woody debris, rocks, or other obstructions), should be performed to allowed sufficient time for stream flow re-stabilization before flow measurements are recorded.

6.1.2 Setup

Once a transect location is selected, the stream flow equipment should be laid out as close to the transect as safety allows.

- Lay out tarps near the area where readings are to be performed, one for equipment, and one for staff seating and miscellaneous supplies.
- Unload equipment and setup the workstation, allowing for easy access to needed materials.
- If contaminants are expected (such as pathogens), establish a decontamination area with another tarp where staff will be exiting the stream. Place decontamination supplies (sprayer bottles with bleach solution and distilled rinse water) in this area.
- If the banks of the stream are steep, place a ladder against the bank for safe ingress and egress.

6.1.3 Setting up the Transect

If the stream to be sampled is more than a few (five) feet across and the bottom profile of the stream is geometrically complicated, a transect for defining the area of the stream (by defined small sub-areas of depth) will be defined and measured in the field. The following procedures describe the process for setting up the transect.

- Setup the transect endpoints by driving a stake into the ground on each side of the stream. The resulting transect should be at right angles to the stream flow.
- Stretch a line (polyester pre-stretched line) across the stream and fasten to each stake, ensuring the line remains taut and as near the surface of the water as possible.
- Facing upstream, align the zero increment of the tape measure with the left edge of water and mark the line or secure the measuring tape to the line across the width of the stream using zip ties. If available, fasten the side of the tape measure marked in tenth of foot increments face-up. It may be convenient to fasten the tape measure to the line at the specific locations where measurements will be taken.

- Measure the total width of the stream.

- Determine the spacing of the stream velocity readings to be collected based on the width of the stream. The reading locations should be tenths of feet; equal distances apart, with 20 to 30 readings for streams wider than 20 feet, at one-foot intervals for streams between 5 and 20 feet wide, and 0.2 feet for streams less than 5 feet wide. For example, if a stream is 46 feet wide, a spacing of 2 feet (24 readings including both edges) would be preferred to a spacing of 1½ feet (30 readings). The first and last reading locations for each transect should fall at or outside the left and right edges of the water and will have zero velocity and zero depth.

If a boat or raft will be used to take the readings because the stream cannot be safely waded, the boat or raft must be stabilized against movement at each transect station but allowed to be moved across the stream as measurements dictate. A line (preferably polyester pre-stretch) tied to existing secure objects such as trees, guardrails, or other stationary objects (one on either side of the stream) should be attached to the boat through cleats, cams or eyelets on the boat or raft (and secured by appropriate knots (such as a bowline)) to enable the line to be untied. The objects should be as far upstream of the transect as the width of the stream. The lines must be independently adjustable on the boat to allow for freedom of movement along the transect yet allowing stability from downstream or lateral drift. If stationary objects are not available, vehicles, securely driven stakes, or two secure anchors on each stream bank may be necessary. Motors, if used, should not be used during actual velocity readings or sample collection.

6.1.4 Measurement of Stream Depth

The depth of the stream should be measured at each point of the transect using equipment specific to the approximate depth encountered. For depths less than 5-feet, a staff gauge or steel measuring tape, in a vertical position, can be used to measure depth directly in feet and tenths of feet. If the velocity of the stream is too great, the turbulence around the gauge may make accurate and reproducible readings difficult. In this case, a PVC pipe, longer than the stream is deep and perforated near the bottom to allow communication with the stream flow, can be used to minimize the turbulence around the staff gauge while measuring the depth. The tube should be placed in the location of the measurement, the water level in the tube allowed to come to equilibrium and then the staff gauge used through the tube. Care should be taken to not disturb the sediment or organisms on the bottom of the stream bed.

For greater depths, a graduated measuring, and weighted, line may be used or an electronic depth meter for situations such as lakes and deep ponds.

6.1.5 Measurement of Stream Velocity

There are a number of velocity measuring methods/devices that can be used for determination of the stream velocity at each sampling location or at each point of a transect. The methods for velocity determination will be defined in the work plan with the prior knowledge of each sample collection point location. The procedures for the proper calibration and use of velocity meters are well defined by the US Geological Survey and other State and Federal agencies as well as manufacturers of the meters. The measurements should follow these procedures and be made by staff with experience with the meters to be used.

For streams with simple geometry and steady laminar flow, the flow may not deep enough to fully submerge any of the available flow velocity meters. In this instance a simple method for velocity determination is to measure the rate of travel of a float on the surface of the water using a defined distance along the axis of the stream an accurate stop watch. If this method is used at least 10 repetitions of the measurement should be made and a calculated average of the 10 velocities used in the subsequent volumetric flow determination. Regardless of stream width, a minimum of two passes of velocity measurements should be taken; once traveling left to right facing upstream, once traveling right to left facing upstream.

For most stream flow situations that may be encountered, where the stream can be safely waded, a velocity reading should be collected at each transect location using a calibrated velocity meter such as a Pygmy meter, Price AA meter, Acoustic Doppler Meter or Marsh-McBirney electronic direct reading meter. For each of these, a vertical profile of the stream velocity, at each transect whole foot location (see above) shall be measured as follows:

- Depths ≤ 2.5 Feet: One measurement should be taken at 60% of the depth at each measurement location.

- Depths >2.5 Feet: Two measurements should be taken: at 20% and 80% of the total depth at each measurement location.

The use of these in-stream measuring devices usually includes the use of a Wading Rod, which is a tool that is designed and constructed to easily set and hold the flow meter at the desired location and the desired depth (20%, 60% or 80%) using a defined set of gradations on the Wadding Rod and instructions that accompany the meters.

6.1.6 Measurement of Flow Velocities

For all velocity readings, the Wading Rod should be kept vertical and the meter perpendicular to the flow. For those streams with multiple measurements across a transect, measure and record the velocity, move to the next location along the transect, and repeat the procedure until reaching the opposite bank. At least one measurement should be made at each pre-determined measurement point along the transect, however additional measurements along the transect can be used to help average the flow if the site conditions suggest that this is appropriate.

6.1.7 Calculating Stream Flow

Once the velocity and depth of the points along the transect have been determined, the midsection method can be used for determining the stream flow. Compute the volumetric flow in each transect increment by multiplying the averaged velocity, or single velocity in streams less than 2.5 feet deep, in each increment by the area determined for that transect increment (depth times width). Note that the first and last increments are located at the edge of the stream and have a depth and velocity of zero. Sum the volumetric flow for each increment to compute total stream flow. Record all measurements and the resulting flow in cubic feet (or cubic meters) per second on the appropriate field forms.

6.1.8 Volumetric Flow Measuring Structure

The one-inch Parshall cutthroat flume may be utilized along sections of streams that are narrow (usually < 2.5 feet wide), shallow and somewhat confined that inhibit the use of the velocity meter. The flume can be installed on a straight section of stream with a smooth cobble-free bottom. Level the flume with a torpedo level to ensure accurate readings on the gauge that is attached to the upstream inlet portion of the flume. Once the flume is level and stable, tightly place sand bags on both sides of the flume until all the stream flow is channeled through the flume. Record two measurements off the flume gauge and document them on the Stream Flow (Discharge) Measurement Form. Also document the estimated stream flow loss around the flume, flume type, flume width and final discharge including estimated losses (CFS) on the Stream Flow (Discharge) Measurement Form. The flume gauge records head feet and will need to be converted into cubic feet per second using the manufacture's (Virtual Polymer Compounds, LLC) conversion chart.

6.1.9 Graduated Bucket Flow Measurement Method

Stream flow can be measured utilizing the graduated bucket method if flow in the stream is diverted through a culvert or pipe. For higher flow rates, a graduated 5-gallon bucket will be used and for lower flow rates a graduated 1-gallon bucket is sufficient. This method will involve using a stop watch –to recordthe number of seconds it takes to fill the graduated bucket to a specified graduated mark. Continue until at least three consistent measurements are obtained. Once three consistent measurements are obtained, the flow rate will be calculated by dividing the volume in the graduated bucket by the average time required to fill the volume. Typically flow rates will be recorded in gallons per minute (gpm).

6.2 SURFACE WATER SAMPLING

Preparation and execution of surface water sampling will be performed by appropriately trained field staff under the guidance of a California-licensed Professional Geologist, Hydrologist, or Professional Engineer. Surface water sampling preparation and surface water sampling techniques will be defined in the work plan and general requirements are discussed below.

6.2.1 Preparation

Prior to performing the sampling, the following tasks will be completed:

- Determine the extent of the sampling effort, the sampling methods to be employed, and which specific equipment and supplies are needed (these will be defined by the stream, lake or pond characteristics and the contaminants of concern).
- Obtain necessary sampling and monitoring equipment.
- Decontaminate all sampling equipment and ensure that it is in working order.
- Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
- Scout proposed locations to ensure accessibility and sampling feasibility.
- Use stakes, flags, or buoys to identify and mark all planned sampling locations. If required, the proposed locations may be adjusted based on site access, property, boundaries, and obstructions.

Things to consider before sampling include:

- Will the sample be collected from the shore or from a boat on the impoundment?
- What is the desired depth at which the sample is to be collected?
- What is the overall depth and flow direction of a river or stream?

- What is the chemical nature of the analyte(s) of concern? Do they float on the water surface (collect by skimming the surface) or are the miscible (soluble) and are more likely to be present at depths (collect sub-surface)?

These considerations will help to dictate the sample equipment to be used during the sample collection.

6.2.2 Surface Water Sampling Techniques

Sampling of both aqueous and non-aqueous liquids is generally accomplished through the use of one of the following samplers or techniques:

- Dip Sampler;
- Direct Method;
- Discrete Depth Samplers;
- Peristaltic Pumps.

Sampling situations vary widely and other techniques may be available, however these sampling techniques will allow for collection of representative samples from the majority of streams, rivers, lakes and ponds.

Sample collection devices must be of a proper composition based upon the analyses to be performed. For example, devices which are free of metal surfaces should be used for collecting samples for metal analyses. The SAP and work plan will define the materials of construction that can come into contact with the water to be sampled as well as the laboratory prepared sample containers and preservatives (if any) to be used for the water samples.

6.2.2.1 Dip Sampler

A dip sampler is useful for situations where a sample is to be recovered from an outfall pipe or along a stream, lake or pond where direct access is limited. Generally a dip sampler is a sample collection container (either open of capable of closing upon sample collection) mounted on a long pole that may be telescoping. The long handle on such a device allows access from a discrete location. Sampling procedures are as follows:

1. Assemble the device in accordance with the manufacturer’s instructions.
2. Extend the device to the sample location and collect the sample.

3. Retrieve the sampler and transfer the sample to the appropriate sample container.

6.2.2.2 Direct Method

For streams, rivers, lakes, and other surface waters, the direct method may be utilized to collect water samples from the water surface. This method is typically not used for sampling lagoons, impoundments, or ponds where significant concentrations of contaminants are present.

Use adequate protective clothing and gain access to the sampling station by appropriate means. For shallow stream stations, the sampler should face upstream and collect the sample upstream from where the sample personnel are standing and without disturbing sediment. Surface water samples should always be collected prior to a sediment sample at the same location. Submerge the closed sample container, open the bottle to collect the sample, and then cap the bottle while it remains under water.

When using the direct method, do not use pre-preserved sample bottles as the collection method may dilute the concentration of preservative necessary for proper sample preservation.

6.2.2.3 Discrete Depth Samplers

When samples are to be collected from discrete depths of a stream, river, lake or pond, the predetermined depths and contaminants of concern will define what specific sample collection devices should be used. There are sample collection devices that can be used to collect samples from shallow water (less than 2.5 feet) which are generally horizontal tubes (Kemmerer sampler) or deeper depths which generally use the same principal of sample collection (Van Dorn Sampler). Both samplers are lowered to the desired sampling depth and allowed to come to equilibrium with the flowing or steady water. The line which holds the sample device is connected to a spring loaded mechanism which allows the ends of the sample tube to close. The sampler is closed by sending a “messenger”, typically a metal weight, down the line to the sampler where then the weight trips the spring and the sampler is closed. The following criteria should be followed:

1. Using a properly decontaminated sampler, set the sampling device so that the sampling end pieces are pulled away from the sampling tube, allowing water to pass through the tube.
2. Lower the pre-set sampling device to the predetermined depth. This requires knowledge of the total depth at the sample location. Avoid bottom/sediment disturbance. The line holding the sampler may need to be pre-marked to ensure that the proper depth is being sampled.

3. When the discrete sampler bottle is at the required depth, send down the messenger to close the sampling device.
4. Retrieve the sampler and discharge the first 10 to 20 milliliter (mL) to clear any potential contamination of the valve. Transfer the water sample to the appropriate sample container in accordance with SOP 1.0 – Field Documentation and Sample Handling and SOP 3.0 – Field Measurements - Water.
5. Be sure to use special attachments available on some discrete samplers to distribute small volumes at low flow rates, when appropriate.
6. Document the surface location of the surface water sample using a GPS device.

6.2.2.4 Peristaltic Pump Samplers

A peristaltic pump can be used to collect a sample from the water column at most depths of interest in a stream or river. Tubing (the composition of which will be defined in the work plan) is lowered to the desired sample depth (using weights to ensure that the tubing is placed to the correct depth) and connected at the surface to the peristaltic pump.

Typically peristaltic pumps work to a depth of approximately 25 feet below ground surface. Because of the overlying water, deeper depths can be sampled but may not be efficient due to the low pumping rates of peristaltic pumps and the sample volume that may be needed for sample analysis. Commercially available pumps vary in size and capability, with some being designed specifically for the simultaneous collection of multiple water samples. Due to the various pumps available no universal sampling procedure is available and the sampler should follow the procedures provided in the instruction manual for the pump.

6.3 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
01	ARC	Section 6.1.8 – added to include flow measurements using a volumetric flow measuring structure Section 6.1.9 – added to include flow measurements using a graduated bucket	6/4/13	LL 6/6/13

ATTACHMENT

- Stream Flow (Discharge) Measurement Form

Stream Flow (Discharge) Measurement Form

Site Description ______________________ Date/Time ______________________
Stream ______________________ Weather ______________________
Samplers Present

Other Notes:

Bucket method: Bucket volume (gal): __________
Fill Times (sec): 1) 2) 3) 4) 5)
Calculated discharge: __________ gpm
divide gpm by 448.8: __________ cfs

Flume method: Flume type: Estimated losses around flume (%):
Flume choke width:

Measurements:	1)	2)	Other Flume Installation Notes:
Upstream Stage (0.1ft):			
Downstream Stage (0.1ft):			
Lookup discharge (cfs):			
Final Discharge including Estimated Losses (cfs):			

Flow Meter method: Flow Meter Type: __________
Pass 1 Calculated Discharge (cfs): Pass 2 Calculated Discharge (cfs):
Average Discharge (cfs):

Pass 1			**Pass 2**		
Flow computer datafile:			**Flow computer datafile:**		
Direction facing upstream; circle (R to L) (L to R)			Direction facing upstream; circle (R to L) (L to R)		
Tape (0.1 ft)	**Depth (0.1 ft)**	**Velocity (ft/s)**	**Tape (0.1 ft)**	**Depth (0.1 ft)**	**Velocity (ft/s)**

7.0 – ROCK DRAIN MATRIX LABORATORY PROCEDURES

Purpose and Scope: The purpose of this document is to provide procedures for anlayzing rock matrix samples for total metals analysis. It includes instructions on the preparation, field sampling procedures, and leachate processing.

Equipment:

Sealable sample collection bags (1 Liter)
500 mL glass beaker
200 mL glass beaker
200 mL pipette
Scale
Oven
Thermometer
Distilled water
Deionized water
Spray water bottles
1% Liquinox® solution
Sample bottles
Sample labels
Custody seals
Fine-tipped permanent markers
Sealable storage bags
Bubble wrap or appropriate packing materials
Blue ice or double bagged ice
Coolers suitable for sample shipment and holding ice
Strapping/packaging tape and shipping labels
Camera with spare memory chip and batteries
Miscellaneous Field Tools:
  Christie Box Opening Tool
  Nitrile Gloves

Documentation:

Daily Field Record (DFR)
Media Sampling Record
Sample Control Log
Maps/Plot Plan
Camera
Photograph Log

This Standard Operating Procedure (SOP) describes the general methodology for collecting rock matrix samples and preparing the rock matrix coating leachate samples for total metals analysis by inductively coupled plasma (ICP) mass spectrometry.

7.1 PREPARATION

Set-up and execution of the rock sampling will be performed by appropriately trained field staff under the guidance of a California- or Colorado-licensed Professional Geologist, or Professional Engineer. Prior to conducting the sampling, the following tasks will be completed:

1. Determine the extent of the sampling effort, the sampling methods to be employed, and required equipment and supplies.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment following SOP 4.0 – Equipment Decontamination and ensure that the equipment is in working order.
4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
5. Scout proposed locations to ensure accessibility and sampling feasibility.
6. Use stakes, flags, or buoys to identify and mark all sampling locations. A GPS maybe used to document the surface coordinates of the sample location.

7.2 FIELD SAMPLING

Rock samples shall be collected in accordance with SOP 13.0 – Soil, Rock, Sediment, and Matrix Sampling. Approximately 500 grams of rock (approximately 20 to 25 rocks) will be collected and placed into a laboratory supplied sampling container. Sampling container will be labeled and packaged for shipment in accordance with SOP 1.0 – Field Documentation and Sample Handling. Sample information will be documented on a Media Sampling Record. Rock matrix samples will be shipped to the selected analytical laboratory for leachate processing and analysis of total metals by ICP.

7.3 LABORATORY SAMPLE PREPARATION AND ANALYSIS

Rock sample leachate shall be obtained and analyzed for each sample as follows.

1. Weigh an empty, clean, 500 mL glass beaker to obtain a tare weight.
2. Remove approximately 200 grams of rocks (10-12 rocks) from sampling container and place them in the 500 mL glass beaker.
3. Weigh the sample and beaker and note the sample mass.

4. Add 150 mL of 1 molar $NH_2OH \cdot HCl$ solution in 0.25% glacial acetic acid to the sample and beaker.

5. Cover the beaker with a distillation glass and heat for four hours at 85 degrees Celsius (°C), stirring the solution every 20 minutes and periodically confirming the temperature.

6. Decant the leachate into a 200 mL glass beaker, and record the volume of liquid recovered.

7. Proceed with standard analytical methods for ICP metals analysis.

8. All materials or equipment that contacts the rock samples, $NH_2OH \cdot HCl$ solution, glacial acetic acid, or leachate shall be properly disposed or decontaminated in accordance with applicable federal, state, and local regulations.

7.4 REVISION LOG

Revision #	Author	Description of Change (Section #)	Reviewer	Date
01	ARC	Revised Section 7.1 and 7.2 to reference relevant SOPs. Refer to SOP 13.0 for sampling collection techniques		

8.0 – WETLAND MATRIX LABORATORY PROCEDURES

Purpose and Scope: The purpose of this document is to provide procedures for analyzing wetland matrix samples for total metals analysis. It includes instructions on the preparation, field sampling procedures, and digestion and filtrate processing.

Equipment:

- Sealable sample collection bags (1 Liter)
- 500 mL glass beakers (three)
- 250 mL pipette
- Scale
- Distilled water
- Deionized water
- Spray water bottles
- 1% Liquinox® solution
- Sample bottles
- Sample labels
- Custody seals
- Fine-tipped permanent markers
- Sealable storage bags
- Bubble wrap or appropriate packing materials
- Blue ice or double bagged ice
- Coolers suitable for sample shipment and holding ice
- Strapping/packaging tape and shipping labels
- Camera with spare memory chip and batteries
- Miscellaneous Field Tools:
    - Christie Box Opening Tool
    - Nitrile Gloves

Documentation:

- Daily Field Record (DFR)
- Media Sampling Record
- Sample Control Log
- Maps/Plot Plan
- Camera
- Photograph Log

This Standard Operating Procedure (SOP) describes the laboratory procedures for preparing the matrix digestion/filtrate samples for total metals analysis by inductively coupled plasma (ICP) mass spectrometry.

8.1 PREPARATION

Set-up and execution of the rock sampling will be performed by appropriately trained field staff under the guidance of a California- or Colorado-licensed Professional Geologist, or Professional Engineer. Prior to conducting the sampling, the following tasks will be completed:

1. Determine the extent of the sampling effort, the sampling methods to be employed, and required equipment and supplies.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment following SOP 4.0 – Equipment Decontamination and ensure that the equipment is in working order.
4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
5. Scout proposed locations to ensure accessibility and sampling feasibility.
6. Use stakes, flags, or buoys to identify and mark all sampling locations. A GPS maybe used to document the surface coordinates of the sample location.

8.2 FIELD SAMPLING

Wetland matrix samples shall be collected in accordance with SOP 13.0 – Soil, Rock, Sediment, and Matrix Sampling. Approximately 500 grams of matrix will be collected and placed into a laboratory sampling container. Sampling container will be labeled and packaged for shipment in accordance with SOP 1.0 – Field Documentation and Sample Handling. Sample information will be documented on a Media Sampling Record. Rock media samples will be shipped to the selected analytical laboratory for leachate processing and analysis of total metals by ICP.

8.3 LABORATORY SAMPLE PREPARATION AND ANALYSIS

Wetland matrix substrate digestion shall be conducted and analyzed for each sample as follows. The digest shall be performed in a ventilated fume hood, as it is possible that toxic hydrogen sulfide fumes will be released during the digestion.

1. Weigh an empty, clean, 500 mL glass beaker to obtain a tare weight.
2. Remove approximately 100 grams of the sample material from the plastic bag and place in the 500 mL glass beaker.
3. Weigh the sample and beaker and note the sample mass.

4. Add 200 mL of 6 molar cold hydrochloric acid (HCl) to the sample and beaker and digest for one hour, stirring digest every 20 minutes.

5. Decant the digest into a 500 mL glass beaker.

6. Filter the digest using a paper filter, and record the filtrate volume. Discard the used filter.

7. Proceed with standard analytical methods for ICP metals analysis.

8. All materials or equipment that contacts the wetland organic substrate, H_2O_2, HNO_3, digest, or filtrate shall be properly disposed or decontaminated in accordance with applicable federal, state, and local regulations.

8.4 REVISION LOG

Revision #	Author	Description of Change (Section #)	Reviewer	Date
01	ARC	Revised Section 8.1 and 8.2 reference relevant SOPs. Refer to SOP 13.0 for sampling collection techniques		

9.0– OPERATION AND MAINTENANCE OF AUTOMATIC WATER SAMPLING EQUIPMENT

Purpose and Scope: The purpose of this document is to describe the procedures for the operation and maintenance (O&M) of the automatic water sampling equipment to collect discrete grab samples. This SOP presents:

- Installation and Setup Automatic Water Samplers
- Programming of Automatic Water Samplers
- Testing Sampler Programs
- Daily O&M Activities

Equipment:

HACH® Sigma 900 MAX Portable Sampler;
Velocity area sensor;
Water quality probes (pH, DO, and EC);
Calibration solutions;
DO membrane filters;
Thermometer;
Neoprene waders;
Steel toe rubber boots;
Pencils or waterproof pens;
Digital camera;
5-gallon buckets;
Graduated cylinder; and
Miscellaneous tools:
  Screwdrivers (micro);
  Adjustable wrenches;
  Cable ties; and
  Spray bottles (one with Liquinox® and distilled water and one with distilled water).

Documentation:

HACH Sigma 900 MAX Portable Sampler Instrument Manual (Instrument Manual);
HACH Submerged Area/Velocity Sensor User Manual;
HACH DO Sensor Manual;
Daily Field Record (DFR);
Field Instrument Calibration Sheet;
Automatic Sampler Inspection and Sampling Record (attached)
Calibration Standard Data; and
Maps/plot plans.

9.1 INSTALLATION AND SETUP OF AUTOMATIC WATER SAMPLING EQUIPMENT

This section describes the general procedures for setting up the automatic water samplers. This task will include the installation of the HACH® Sigma 900 Max Portable Samplers (automatic water samplers), water quality probes (if installed), and velocity area sensors (if installed).

9.1.1 Automatic Storm Water Samplers

The automatic water samplers and water quality probes will be installed at each monitoring station. Following the installation, the samplers will be programmed and sampling programs will be tested prior to using the device for sample collection. The setup procedures are identified below:

- Install automatic water sampler (ensure sampler enclosure is placed onto a flat surface).
- Install calibrated velocity area sensor using the procedure presented in Section 9.1.2.
- Replace desiccant in the canister tube attached to the velocity area sensor.
- Place charged battery into designated enclosure.
- Assemble the DO probe using the procedure described on pages 5 through 7 of the DO Sensor Manual.
- Install the water quality probe/s at each monitoring station.
- Install new 3/8-inch vinyl intake sample tubing with stainless steel strainer attached at the end of the tubing.
- Connect water quality probes and power source connectors to automatic sampler.
- Calibrate water quality probe/s using the procedure presented in Section 9.4.2.1 and pages 70 through 77 of Instrument Manual included as Attachment 1.
- Install sample bottles into sampling tray.
- Confirm the distributor arm is functioning properly.

9.1.2 Velocity Area Sensors

If installed, the velocity sensor will be calibrated to ensure accuracy of the level and velocity measurements. The calibration instructions are presented on page 62 and 63 of the Instrument Manual. Following the calibration of the sensor, return to the status menu of the automatic sampler, document level recorded by the sampler and compare to the actual water level in the bucket to confirm that the calibration of the sensor was successful. To assess the current measured level on the automatic water sampler, press "Main Menu "on the display screen and select "Status" and scroll to the current level measurement.

Following the calibration of the velocity area sensor, the sensor will be mounted with the angled side of the sensor facing into the direction of flow. The velocity area sensor will be installed directly into creek on a mounting bracket approximately at the lowest part of the channel or directly to the bottom of a flow control structure.

9.2 PROGRAMMING OF AUTOMATIC WATER SAMPLING EQUIPMENT

This section describes the basic programming of the velocity area sensors (if installed), setup of the flow meter, and programming automatic water samplers to collect discrete grab samples.

9.2.1 Velocity Area Sensor Setup

The necessary inputs for the programming of the velocity area sensors include velocity direction, velocity units, velocity cutoffs, and default velocity. The instructions for velocity area sensor programming are discussed on pages 61 and 62 of the Instrument Manual. This program feature is optional. To setup the velocity area sensor, from the Main Menu of the automatic storm water sampler, select → Options → Advanced Options →Velocity Setup and enter the necessary parameters, if velocity area sensor is installed.

9.2.2 Flow Meter Programming

The flow meter setup will allow for the sampler to calculate the flow rate at each monitoring station based on the inputs from the velocity area sensor and characteristics of the channel, pipe, weir, or other flow control structures at each sampling location. This programming feature is optional. The flow meter setup can be accessed from the Main Menu of the automatic storm water sampler, select → Options → Advanced Options →Flow Meter Setup.

9.2.3 Basic Programming of Automatic Water Samplers

This section describes the basic programming of the automatic water samplers to collect discrete grab samples. The sampler can be programmed to collect time-proportional samples or triggered to collect a sample when a user specified setpoint is exceeded.

The necessary inputs for the basic programming of the automatic water samplers are included in the Instrument Manual (included as Attachment 1) on pages 37 through 49, and selected programming features are presented below.

The basic programming features can be modified from the Main Menu of the automatic water sampler, select Setup → Modify All Items.

9.2.3.1 Bottles

Samplers will be equipped with 24 1-L, eight 2.7-L, or four 1-gallon polyethylene sampling bottles. The type of bottle selected will be dependent on the number of samples that need to be collected daily and the volume that must be collected for each sampling event. The sampler will be configured with the appropriate bottle retainer to hold sample bottles in place within the base of the sampler.

9.2.3.2 Intake Tubing

The intake tubing length and diameter affects the calculation of sample volume aliquot. The intake tubing is 3/8-inch vinyl, and the tubing length is dependent on the distance from the sampling location to the automatic sampler. The length of the tubing installed at each location will be determined in the field.

9.2.3.3 Sample Collection

Discrete samples will be collected by programming the sampler to collect timed-proportional samples which will allow for samples to be collected each time a user specified time interval has lapsed. For example, to program the sampler to collect a discrete sample every 2-hours, the user will select Timed Proportional under the Sample Collection option → enter the Time Interval Between Samples (i.e., hh:mm, 02:00) → select Take First Sample Immediately.

9.2.3.4 Sample Distribution

The sample distribution option allows for multiple samples to be collected during each programming event. For example, if the user wishes to collect 12 discrete samples in a 24-hour period, select the Sample Distribution Option→ select No for Deliver Each Sample to All Bottles

→ Select Samples per Bottle, → select Samples per Bottle for Method of Distribution, → enter 1 for Samples per Bottle.

9.2.3.5 Advanced Sampling Options – Setpoint Sampling

Setpoint sampling will be selected under the Advanced Sampling Options to allow for the user to establish an upper limit (high trigger) that will initiate sampling. The high trigger setpoint will be a specified water level. The program will be halted once the level goes below the user defined high trigger setpoint. See pages 50 through 52 of the Instrument Manual for programming instructions.

9.2.3.6 Data Logging

At the sampling station, the sampler will be programmed to log selected inputs in 15 minute intervals. To access Data Log Menu, from the Main Menu, select Options → Advanced Options→ Data Log.

9.3 TESTING SAMPLING PROGRAMS

The sampler program will be tested at each monitoring station prior to the initiation of the sampling program to ensure parameters are correctly programmed.

At the end of the test collection period, return back to the sampler to:

- Download data.
- Review sampling history.
- Assess how much sample was collected in the sampling container/s.
- Discard sample/s collected during the test collection period.
- Decontaminate the sampling container/s or replace with replacement sampling container/s.
- Reset sampling program.

All observations during this sampling test will be documented in the DFR. Any issues should be immediately discussed with the Project Manager or designee.

9.4 OPERATIONS AND MAINTENANCE PROCEDURES

This section describes the routine and weekly O&M activities to be conducted of the automatic water samplers.

9.4.1 Routine Operations and Maintenance

The routine maintenance O&M activities to be conducted when water samples are retrieved from the automatic samplers will include the following tasks:

1. Retrieve samples from automatic sampler. Sample handling and other water sampling procedures are presented in SOPs 1.0 and 2.0.
2. Replace and/or decontaminate any bottles that were filled. Decontaminate bottles using the procedures described in SOP 4.0.
3. When replacing the bottle/s, ensure the bottle/s are placed in the correct location in the sampling tray and make sure the distributor arm is placed on top of the first sampling bottle. Bottle placement is shown on pages 29 through 30 of the Instrument Manual.
4. Record how many samples were collected since the last inspection, the start and end time (if applicable) of sample collection, if samples were collected on an Automatic Samper Inspection and Sampling Form (attached). The sample collection time is the time that the last sample aliquot was collected on the automatic sampler.
5. Download logged data from the automatic sampler which may include, velocity, water level, rainfall, pH, dissolved oxygen (DO), EC, temperature data to laptop computer that has the Insight software installed (See Section 9.4.1.1). This step is not necessary if the sampler is not equipped with water quality probes and/or a area/velocity sensor.
6. Reset sampler program and delete logged data.
7. Record the current parameters at each monitoring station, if sampler is equipped with water quality probes and velocity area sensor. From the Main Menu → select Status. Based on the logged parameters at each station, the status menu should display current level, flow, total flow, velocity, pH, DO, DO temperature, EC, EC temperature, and battery charge level.
8. Replace battery with charged battery if charge level is less than 11.5 volts.
9. Verify that the sample intake tube, area/velocity sensor, and water quality probes are intact and free of sediment. Clean probes if necessary using a small scrub brush and Liquinox®/water mixture and rinse with fresh water.

10. If installed, confirm that pH and DO probes are submerged. If probes are barely submerged, remove from the monitoring station and reprogram the Data Log Inputs of the sampler.

11. Note all observations on the Automatic Sampler Inspection and Sampling Record (attached).

12. Prior to leaving each sampling station, ensure downloaded data has been saved onto the laptop and the sampling program has been reset. Whenever modifications are made to the sampling program, the logged data on sampler will be deleted.

9.4.1.1 Data Downloading Procedures

Data from the samplers must be downloaded every day samples are retrieved from the samplers if water quality parameters and/or velocity area sensors are equipped on the automatic water samplers and programmed to log data. Steps for downloading sampler data are as follows:

1. Load the program “Insight” from the following link: http://www.hach.com/hc/view.file.categories.invoker/FILCAT_SOFTWARE_FLOWSAMP/NewLinkLabel=Flow+and+Sampling+Products+Software+Downloads

2. Install the USB adapter onto your computer, using the software provided with the adapter to download USB driver.

3. Connect the adapter to the HACH sampler connection cable.

4. Connect the other end of the HACH cable to the “RS-232” port on the Sigma 900 Max Sampler.

5. Open up the Insight program on the laptop computer.

6. From the buttons near the top of the screen, click the “900 max” button

7. A new screen will pop up. The Baud rate should be the default value of 19,200. The port will be whatever port you choose to use on your laptop. (If you do not know which port you are using, please use the following path. For Windows XP users, go to Control Panel → System → Hardware Tab → Device Manager → Ports (COM & LPT). There you will find the list of ports on your computer that are being used.)

8. Once the Baud Rate and Port have been entered, click the OK button to connect to the sampler.

9. Once connected, the first button at the top of the screen is Download All Data

10. Then choose to Download All Data.

11. Then click OK to download information.

12. Once all the information is downloaded, save the data.

13. Click on “Open Database”, select file, and verify that data was successfully downloaded for all inputs (pH, DO, EC, flow, velocity, level, rainfall, etc.).

14. Disconnect the cable from the sampler.

15. Downloaded data files should be transferred to the Project Manager approximately weekly.

9.4.1.2 Resetting Automatic Sampler Programs

Following the download of logged data, the sampling program at each monitoring station will be modified. If no modifications are necessary to the sampling programs, be sure to halt the sampling program by pressing the Halt button on the sampler and restart the program by pressing the Start Button and select Start from the beginning. Prior to leaving sampler, insure Running is shown on the bottom left hand corner of the sampler display screen.

9.4.1.3 Checking Battery Charge Levels

To check the battery charge level, from the Main Menu → select Status and scroll down to read battery voltage remaining. If voltage displayed is 11.5 volts or less, then replace battery with a fully charged spare battery.

9.4.2 Weekly Operations and Maintenance Procedures

This section describes the weekly O&M of the automatic water samplers. These procedures are only necessary if the automatic sampler is equipped with a velocity area sensor and water quality probes.

1. Verify the level recorded by the automatic sampler using a tape measure or staff gauge (if installed).

2. Measure pH, DO, EC, and temperature using calibrated hand-held meter (YSI 556 or similar) and compare to sampler readings to determine if calibration is necessary. Criteria for sensor calibration are present in Section 9.4.2.1.

9.4.2.1 Checking Level Recorded by Automatic Sampler

To assess if a level adjustment is necessary, a measurement of the actual water level will be compared to the recorded value on the sampler. To check the current level, from the Main Menu → select Status and scroll down to read the level. If the relative percent difference is greater than 10%, a level adjustment will be performed. Level adjust can be accessed from the Main Menu → Options → select Level Adjust to change the level.

9.4.2.2 Calibrating Water Quality Probes

Calibration checks will be performed weekly to assess if the water quality probe/s need to be re-calibrated, if installed. To check the current measurements recorded by the sampler, select “Status” from the Main Menu and scroll down to read the current pH, DO, EC, and temperature measurements and record on the Automatic Sampler Inspection and Sampling Record (attached).

If the relative percent difference between hand held water quality meter and the sampler readings is greater than 20%, the probe will be recalibrated using the procedures presented below.

Access the probe calibration function on sampler from the Main Menu→ select Options→ Advanced Options→Calibration → then select appropriate probe.

<u>pH Probe Calibration</u>

For pH probe calibration, select two pH buffer solutions that bracket the current pH measurement recorded on the hand-held meter (pH 4.0, pH 7.0, and pH 10.0). Record temperature of the first calibration solution and refer to the Calibration Standard Data to determine the pH of the solution at that temperature. Submerse the pH probe in the first standard solution, allowing for the probe and solution temperatures equilibrate. Follow the instructions on page 70 of the Instrument Manual for the remainder of the pH probe calibration instructions.

<u>EC Probe Calibration</u>

For EC probe calibration, record the temperature of the EC calibration solution and refer to Calibration Standard Sheet to determine the EC at that temperature. Submerse the EC probe in the standard solution, allowing for the probe and solution temperatures equilibrate. Follow the instructions on pages 76 - 77 of the Instrument Manual for the remainder of the EC probe calibration instructions.

DO Probe Calibration

For DO probe calibration, record the ambient air temperature using a thermometer. Remove the DO probe from water and allow for probe temperature to equilibrate with the ambient air temperature. The salinity of the flow stream at all stations is assumed to be zero. Follow the instructions on page 74 of the Instrument Manual for the remainder of the DO probe calibration instructions.

If error message "output voltage too low to calibrate" appears on the sampler screen, replace the DO probe membrane and electrolyte solution in the probe. Using the procedures described on pages 5 through 7 of the DO Sensor Manual.

9.5 CLEANING AUTOMATIC SAMPLING EQUIPMENT

At the end of sampling, water quality probes, velocity area sensors, and the automatic storm water samplers will be disassembled and decontaminated.

- Disconnect the DO probes and clean according to the instructions on pages 11 and 12 of the DO Sensor Manual.
- Disconnect the pH probes and clean with distilled water and Liquinox®. Replace the wetting cap filled with pH 4.0 solution.
- Disconnect the EC probes and clean with distilled water and Liquinox®.
- Disconnect the velocity area sensor, if installed, and clean sensor according to the instructions on pages 17 through 19 of the Submerged Area/Velocity Sensor User Manual.
- Decontaminate all sample bottles.
- Decontaminate the sample bottle holding trays.

9.8 REFERENCES

Hach, 2003. Instrument Manual: Hach Sigma 900 MAX Portable Sampler.

9.9 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
01	ARC	Minor editorial changes. Section 9.5 - Removed weekly data analysis section not applicable. Revised automatic sampling inspection and sampling record	6/4/13	LL 6/6/13

ATTACHMENTS

- Automatic Sampler Inspection and Sampling Record

AUTOSAMPLER INSPECTION AND SAMPLING RECORD
Rico-Argentine Mine Site - Rico Tunnels

Location ID: ______________________
Tracer / Injection Chemical: ______________________
Method of Sampling: ______________________
Samplers Name: ______________________
Samplers Signature: ______________________
Date and Time of Inspection: ______________________

Sample ID[1]	Date	Time	Field Water Quality Measurements[2,3] Temp (° C)	SEC (µs/cm)	DO (mg/L)	pH (s.u.)	ORP (mV)	Field Analytical Test[4] Total Alk (mg/L $CaCO_3$)	Dissolved Bromide[6] (mg/L)	Dissolved Chloride[6] (mg/L)
How many successful samples were collected since last inspection?										
Were there any missed samples?										
Confirm that sample bottles were replaced decontaminated sampling bottles.										
Confirm that sampling program was reset.										

Notes:
1. List sample ID if sample is submitted for laboratory analysis.
2. Measured with a calibrated multiparameter meter or automatic sampler.
3. Record water quality parameters at the time when the sample was collected as recorded by the or multiparameter meter and autosampler.
4. Measured with photometer or an ion-specific electrode.
6. Only record bromide and chloride during the tracer injection tests.

10.0– GROUNDWATER SAMPLING

Purpose and Scope: The purpose of this document is to present procedures for collecting a groundwater sample for chemical analysis. It includes a discussion on sampling preparations, field procedures, piezometer sampling, and grab groundwater sampling.

Equipment:

- See Equipment List in SOP 3.0 - Field Measurements -Water
- Bailer (Teflon, Polyvinyl Chloride (PVC), polyethylene, or equivalent)
- Bailer reel with twine or rope
- Flow through cell (for ORP and DO measurements)
- Sample containers (laboratory cleaned and provided)
- Electric generator
- Electric submersible pump control box
- Oil-less compressor
- Groundwater pump (e.g., submersible pump, peristaltic pump, bladder pump, etc.)
- Ice chests
- Packaging tape
- Zip lock bags (2-gallon and 1-gallon)
- Double bagged "wet" ice
- 5-gallon buckets
- Graduated cylinder
- Stop Watch
- Miscellaneous tools
- Safety Equipment

Documentation:

- Daily Field Record (DFR)
- Sample Control Log
- Atlantic Richfield Chain-of-Custody (COC) form
- Multi-parameter Calibration Sheet
- Turbidity Calibration Sheet
- Well Sampling Record (attached)
- Shipping labels
- Maps/plot plan
- Camera

Water sampling activities generally are performed after water table elevations have been measured and stagnant water within the wells has been purged. This Standard Operating Procedure (SOP) describes the purging and groundwater sampling procedures to be performed in monitoring wells, piezometers, temporarily cased, and open boreholes. These procedures may be adapted to other structures that need to be purged and sampled, such as the rock drain and wetland monitoring ports.

All groundwater sampling will be performed by appropriately trained field staff under the guidance of an appropriately licensed Professional Geologist or Professional Engineer.

10.1 Preparation and Set-up

Preparation and set-up for water sampling will include the following:

- Review the above listed SOPs and obtain, prepare, and maintain all applicable field forms.
- Review the scope of work and take note of the proposed sample locations, number of samples, and list of analytes to be collected. Verify the proposed samples with the Project Manager or designee.
- Notify the laboratory 2-3 weeks in advance of sampling of the number of samples and types of analyses. Confirm preservation and handling requirements with the laboratory. Arrange for the laboratory to ship appropriate containers and sample coolers to the office prior to mobilization to the site, and upon receipt, inspect sample containers and notify laboratory of any missing or damaged containers.
- Coordinate and provide notification of the sampling schedule to the Project Manager (or designee) and other affected individuals, and clear access to wells.
- Prior to performing sampling activities, calibrate, in accordance with manufacturer's instructions, the pH, specific electrical conductance (SEC), temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity meters to ensure the meters are in good working condition and providing accurate measurements. Document the results of each calibration on the appropriate Calibration Sheet (SOP 3.0 – Field Measurements – Water).
- Assemble all other required equipment and check that it is in proper working condition.
- Ensure all sampling equipment has been decontaminated (SOP 4.0 – Equipment Decontamination). If dedicated or disposable sampling equipment is used, decontamination activities will not be needed.

10.2 General Sampling Procedures and Standard Flow Purging and Sampling Method

This SOP outlines several sampling techniques. During planning, the project team must evaluate the project data quality objectives and physical setting of the site to decide which sampling technique is most appropriate to meet the objectives of the sampling effort.

Document general field activities on a DFR (SOP 1.0 – Field Documentation and Sampling Handling). Prior to purging, visually check the well for damage and begin to prepare the Well Sampling Record.

The static water level will then be measured according to the procedures outlined in SOP 3.0 – Field Measurements – Water. Depth-to-water measurements will be recorded to the nearest 0.01-foot and recorded on the Well Sampling Record. Monitoring well construction logs, along with available water level data, will be reviewed to determine the volume of water to be purged.

Each well will then be purged to allow collection of a representative sample. Monitoring wells will be purged using bailers or pumps (e.g., submersible, bladder, or peristaltic). If a submersible pump is used, the purge rate will be determined for the well by the purge volume. For monitoring wells where the water level is above the screen intervals, the pump intake will be located near the top of the water column, and slowly lowered during the purging process. For water columns within the well screen, the pump intake should be set at a sufficient depth below the water level where drawdown during pumping does not allow air to enter the pump. The purge rate and method may be dependent on the chemical of potential concern, physical constraints, and available equipment. Extracted purged water will be surface discharged and managed in accordance with SOP 5.0 – Investigation Derived Waste Disposal.

During purging, field measurement of pH, SEC, temperature, ORP, DO, and turbidity will be performed periodically. Purging of each monitoring well will continue until the following two minimum conditions are met:

- A minimum of four sets of parameter measurements have been taken.
- Three consecutive readings of field pH, SEC, temperature, ORP, DO, and turbidity measurements of the discharged water taken at least 1 minute apart and meet the stabilization criteria listed in Table 1.

Measurements of ORP and DO require the use of a flow-through cell to obtain accurate measurements. If a flow-through cell is not used, it must be noted on the Well Sampling Record.

For low-permeability formations, there may be no way to avoid pumping and/or bailing a well dry. In these cases, a well may be purged dry. Wells that recharge very slowly may be purged dry once, allowed to recharge, and then sampled after two hours or as soon as sufficient water recharges into the well. In this case, at least two sets of parameter readings of field water quality should be taken, one initially and one after recharge.

If any of the field measurements are suspect, instruments will be re-calibrated. Calibration information will be recorded on the Instrument Calibration Form and noted on DFRs.

Prior to collecting any samples, the field personnel will put on new nitrile gloves. Water will then be pumped or bailed, filtered (if necessary), and decanted into laboratory-supplied containers. A pump (e.g., submersible, bladder, peristaltic) or a disposable bailer will be used to obtain the groundwater samples from the well. When using a submersible pump and a flow-through cell during purging, the flow-through cell must be removed from the sampling stream prior to sampling. When using a bailer for sample collection, gently lower the bailer with minimum splash to just below the water surface so that the potential for aeration of water is reduced.

If multiple types of analyses will be performed, the order in which the sample containers will be filled must be determined based on the sampling task and the end use of the data. In general, sample containers will be filled first for metals analysis followed by the other chemical constituents.

Samples collected for metals and other inorganic analysis will be filtered and preserved in the field according to laboratory instruction. Sample preservative requirements are provided in the applicable SAP. Samples that require filtering will be filtered using a disposable filter with a filter screen size of 0.45 micrometers (µm, micron filter), or equivalent. A description of the odor or physical appearance of the sample, including color, clarity, suspended solids, etc., will be recorded on the Well Sampling Record.

Labels will be affixed to each sample bottle recording the sample identification number, date, time (military time), analysis required, preservative used, and collector's initials. An Atlantic Richfield COC or laboratory equivalent will accompany each sample to establish the required documentation necessary to trace sample possession. All collected samples, including duplicates and blanks, will be recorded on a Sample Control Log (refer to SOP 1.0 – Field Documentation and Sample Handling).

Non-disposable bailers, pumps, meters, reels, water levels meters, and Teflon tubing will be decontaminated prior to first use and upon completion of sampling (SOP 4.0 – Equipment Decontamination). Soil, water, and waste disposal are discussed in SOP 5.0 – Investigation Derived Waste Disposal.

10.3 PIEZOMETER SAMPLING

A piezometer is a permanent or temporary well that may be designed similarly to a monitoring well. This type of well is primarily used to collect water-level data to aid in interpreting the direction of groundwater flow. Piezometers may be sampled periodically to evaluate water quality, in which case, piezometers will be sampled according to procedures outlined in Section 10.2 General Samplings Procedures and Standard Flow Purging and Sampling Method or Section 10.6 Micro-Purge or Low Flow Sampling Method.

10.4 GRAB GROUNDWATER SAMPLING

Grab groundwater samples may be collected during or immediately after drilling if water from the formation is freely flowing into an open boring.

Grab groundwater samples will be collected according to the procedures outlined above for sampling of monitoring wells with the exception that purging and monitoring of field parameters may not be performed prior to sample collection. However, if water was added to the borehole during the drilling process, an attempt will be made to remove the volume of water added before the grab groundwater sample is collected.

10.5 HYDROPUNCH™ GROUNDWATER SAMPLING

A Hydropunch™ (HP) sampler is a grab groundwater sampling device that is screened over a short interval (generally less than two feet) and can be used to collect a water sample at a relatively discrete interval when compared to traditional wells. If the depths of potential groundwater bearing zones are identified, an HP sampler may be lowered into the open borehole and driven into undisturbed soil by a hammer or direct push. Once the HP sampler is driven into soil, the outer shell of the sampler is retracted to expose a screen. If groundwater is present, it will flow into the sampler through the screen.

If a discrete water sample is desired at a depth already reached by the boring, an adjacent borehole can be installed with an HP sampler to collect groundwater samples at the desired sample depth.

Groundwater samples will be collected from the HP sampler in the same manner as discussed in Section 10.1 Preparation and Set-up with the exception that no purging or monitoring of field parameters will be performed prior to sample collection.

10.6 MICRO-PURGE OR LOW FLOW SAMPLING METHOD

This method assumes the water within the screened interval is not stagnant but flows through the well screen similarly to groundwater flow through the aquifer, and a small change of the natural flow rate in the screened interval will result in samples with particulates and colloidal material representative of groundwater.

Perform the following steps to micro-purge and sample:

- Place the pump and support equipment at the wellhead and slowly lower the pump and tubing down into the monitoring well until the location of the pump intake is set at a pre-determined location within the screen interval. The placement of the pump intake should be positioned with a length-calibrated sampling pump hose, sounded with a weighted tape, or using a pre-measured hose. Record the pump intake location on the Well Sampling Record.

- Measure the water level to the nearest 0.01 foot and record information on the Well Sampling Record; leave the water level indicator probe in the monitoring well.

- Connect the discharge line from the pump to a flow-through cell. A “T” connection may be needed prior to the flow through cell to allow for the collection of water for turbidity measurements. The discharge line from the flow-through cell must be directed to a container to contain the purge water (or placed on the ground in an area that does not create erosion, pooling of water, or migration to a surface water body) during the purging and sampling of the monitoring well.

- Start pumping the well at a low flow rate (0.2 to 0.5 liter per minute) and slowly increase the speed. Check the water level. Maintain a steady flow rate while maintaining a drawdown of less than 0.33 feet (Puls and Barcelona, 1996).

- Measure the discharge rate with a graduated cylinder and a stop watch. Also, measure the water level and record both flow rate and water level on the Well Sampling Record. Continue purging; monitor and record water level and pump rate every three to five minutes during purging. Pumping rates should be kept at a minimal flow to ensure minimal drawdown in the monitoring well.

- During purging, a minimum of one tubing volume (including the volume of water in the pump and flow cell) must be purged prior to recording the water quality parameters. Then monitor and record the water-quality-indicator field parameters every three to five minutes. Typical water-quality-indicator field parameters are turbidity, DO, SEC, pH, ORP, and temperature. Record all of the field parameters measured on the Well Sampling Record. Once the water quality stabilization criteria have successfully been met (Table 1), sample collection can take place.

- If a stabilized drawdown in the well cannot be maintained at less than or equal to 0.33 foot, and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. A check valve is required if the pump is shut off. Under no circumstances should the well be pumped dry. Begin pumping at a lower flow rate. If the water draws down to the top of the screened interval again, turn the pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging, then sampling can proceed the next time the pump is turned on. This information should be noted on the Well Sampling Record with a recommendation for a different purging and sampling procedure.

- Maintain the same purging rate or reduce slightly for sampling (0.2 to 0.5 liter per minute) in order to minimize disturbance of the water column above the screen. Samples should be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell.

TABLE 1: Stabilization Criteria with References for Water-Quality-Indicator Parameters

PARAMETER	STABILIZATION CRITERIA	REFERENCE
Turbidity	+/- 10% (when turbidity is greater than 10 NTUs)	Pulls and Barcelona, 1996; Wilde et al., 1998
Dissolved Oxygen	+/- 0.3 milligrams per liter	Wilde et al., 1998
Specific Electrical Conductance (SEC)	+/- 3%	Puls and Barcelona, 1996
pH	+/- 0.1 standard units	Pulls and Barcelona, 1996; Wilde et al., 1998
Oxydation-Reduction Potential (ORP)	+/- 10 millivolts	Puls and Barcelona, 1996
Temperature	+/- 10 %	----

10.7 REFERENCES

Puls, R.W. and M.J. Barcelona, 1996, Groundwater Issue Paper: Low-Flow (Minimal Draw-down) Groundwater Sampling Procedures; U.S. Environmental Protection Agency, EPA/540/S-95/504, 12pp.

Wilde et al., 1998, National Field Manual for the Collection of Water-Quality Data; U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations.

10.8 REVISION LOG

Revision #	Author	Description of Change (Section #)	Reviewer	Date
00	ARC	Drafted initial SOP. Reviewed by Kent Parrish.	KP	12/17/12
01	ARC	Reviewed SOP. Modified Well Sampling Record to include stabilization criteria and detection limits for standard field analytical methods.		

ATTACHMENT

- Well Sampling Record

WELL SAMPLING RECORD

amec

Well ID: ______________________________

Sample ID: ______________________________

Sample Date: __________ **Sample Time:** ____________

Sample Depth: ______________________________

Project and Task No.: ______________________

Project Name: ______________________________

Date: ______________________________

Initial Depth to Water: ______________________

Total Depth of Well: ______________________

Well Diameter: ______________________

Total Volume Removed (gal): ______________

Purged By: ______________________

Method of Purging: __________ **Sampling:** __________

Pump and Tubing Type: ______________________

Time	DTW (feet btoc)	Cum. Vol. (gal.)	Temp. (°C) [+/- 10%]	SEC (µS/cm) [+/- 3%]	DO (mg/L) [+/- 0.3 mg/L]	pH (units) [+/- 0.1]	ORP (mV) [+/- 10 mV]	Tur-bidity (NTU)	Remarks (color, odor, sediment, approx. purge rate, etc.)

Working Ranges for Frequently Used YSI 9300 Test Methods

Sulfide: 0.01 (DL) – 0.5 mg/L   Fe: 0 (DL) – 10 mg/L

Alkalinity M & P: 10 (DL) – 500 mg/L   Zinc: 0.02 (DL) – 4.0 mg/L

Field Test Method	Result (mg/L)	Dilution Factor	**Final Result:** (multiply by 100 for 1:100 dilution or 50 for 1:50 dilution, etc.) **If result is below working range of meter, report as < DL** **If result is above working range, dilute sample**

QA/QC Sampling & QA/QC Field Test Results

QA/QC Type (duplicate, rinsate blank, field blank)	QA/QC Sample ID	QA/QC Sample Time	Photometer QA/QC Initial Results (mg/L)	Dilution Factor	Final Result (mg/L)

Notes:

Instrument(s) Used (model or unit no.): ______________________________________

(see Instrument Calibration form dated ____________ for calibration details)

Samplers Name:

Samplers Signature:

WELL SAMPLING RECORD

amec

Well ID: ______________________ **Date:** ______________________

Time	DTW (feet btoc)	Cum. Vol. (gal.)	Temp. (°C) [+/- 10%]	SEC (μS/cm) [+/- 3%]	DO (mg/L) [+/- 0.3 mg/L]	pH (units) [+/- 0.1]	ORP (mV) [+/- 10 mV]	Tur-bidity (NTU)	Remarks (color, odor, sediment, approx. purge rate, etc.)

Notes:

\\sac1-fs2\projectf$\Project\16000s\SA11161300 - Rico-Argentine Mine Site\5000_INVESTIGATION\5080 SOPs\QAPP\SOP 10.0 - GW Sampling Rev01\10a_Well Sampling Record_2pgs_rev03.docx

11.0 – AQUIFER TESTING

Purpose and Scope: The purpose of this document is to present procedures for conducting an aquifer test. It describes the procedures to be followed for conducting step-drawdown, constant discharge, slug, and specific capacity tests.

Equipment:

Tape measure (subdivided into hundredths of feet);
Water pressure transducer(s) fitted with a data logger;
Barometric pressure transducer(s) fitted with a data logger;
Communication cable;
Electric sounder;
Stainless steel or PVC slug of a known volume;
Potable water;
Watch or stopwatch with second hand;
Semi-log and/or log-log graph paper (if required);
Thermometer (if transducers are not so equipped);
Appropriate reference material and calculator;
Electrical tape;
Laptop computer or equivalent with Excel™ and transducer communication software installed;
Generator;
Volumetrically graduated container;
Flashlight;
Field water quality meter(s);
Discharge pipe;
Flow meter;
String and reel;
Clamps and vice grips;
Flash light;
Decontamination equipment (buckets, clean/distilled water, brushes, non-phosphate detergent).
Miscellaneous tools (pliers, screwdriver, wrenches, zip ties); and
Safety equipment (At minimum, level D personal protective equipment [PPE], nitrile gloves).

Documentation

Daily Field Record (DFR);
Pressure Transducer Calibration Sheet;
Aquifer Test Data Form (attached);
Maps/plot plan; and
Digital camera.

This Standard Operating Procedure (SOP) describes the general methodology for performing aquifer tests. Aquifer testing methodologies may also be performed in constructed wetland monitoring ports.

All aquifer testing procedures must be performed by appropriately trained field staff under the direct supervision of a licensed Professional Engineer or Professional Geologist.

11.1 GENERAL PROCEDURES

The following general procedures should be performed prior to the start of the test:

- Obtain all appropriate permits according to Federal, State, and local regulations.
- Determine if purge water will be produced, treatment will be needed prior to discharge, and identify if mitigation measures are needed to manage runoff and prevent impacts to the environment (e.g. erosion, flow to ponds and/or creeks). Silt fencing or earthwork may need to be installed downhill of the aquifer test location or equipment may be needed to containerize and transport the fluids prior to disposal. Refer to SOP 5.0 – Investigation Derived Waste Disposal for disposal procedures.
- Communicate with the Project Manager (or designee) on how purge water runoff will be handled so that they can determine if these actions have the potential to impact other site operations (e.g., treatment and/or monitoring systems, roads, etc.).
- Clear the area of obstructions. Contact the Project Manager (or designee) if modifications to the surrounding area are needed (e.g. earthwork, vegetation clearance, impacts to vehicle traffic, SIMOPs).
- Prepare, calibrate, and test any pressure transducers or external data loggers that may be used during the aquifer test in accordance with manufacturer's directions. Complete the pressure transducer calibration sheet. Refer to SOP 14.0 – Continuous Water Levels for operation procedures for pressure transducers.
- Prepare, calibrate, if necessary, and test meters, totalizers, or other equipment to measure groundwater discharge.
- Confirm the aquifer test locations with the Project Manager (or designee).

The following activities must be performed on the day of the aquifer test:

- Document all events and decisions on a DFR. Complete aquifer testing data forms (attached).

- When working in high traffic areas, cordon off work area to restrict access to untrained personnel.

- PPE is appropriate for the conditions is worn within the work zone.

- Setup a decontamination station. Decontaminate all down-hole tools. Refer to SOP 4.0 – Equipment Decontamination.

- Set up a note-taking area.

- Set up a water storage area. If pumped groundwater cannot be released to the ground it may be stored in 55-gallon drums, temporary tanks, or other appropriate containers that can be sealed and transported. If the well is located in an area of uneven terrain, the container should be placed directly on top of the transport vehicle (e.g., flat bed truck). The water storage area should have secondary containment, such as bermed plastic sheeting.

- Monitor the area where pumped water is being released at the surface. Verify that silt fencing or earthwork remains in proper working order (if in use). If needed, water retained behind these features may need to be conveyed or transported and land-applied away from the discharge area. Dispose of the pumped water in accordance with SOP 5.0 – Investigation Derived Waste Disposal.

- Measure the depth to water in the pumping and observation wells. Record the values as pre-test elevations on Aquifer Test Data Form (attached). Install data loggers and pressure transducers in observation wells to record the change in water levels during the aquifer test. The depth that the pressure transducers will be submerged in water will be dependent on the limits of the pressure transducer. The pressure transducers should be placed at the greatest possible depth within the manufacturer's specified pressure range. Refer to the manufacturer's recommendations for proper operation.

- Synchronize the data logger in the transducer with the field laptop's internal clock and set the start times.

- Perform the aquifer test at the pre-determined start time. For pumping tests, change the discharge rate as specified in the work plan. Aquifer pumping tests are generally performed over several days.

- Provide the pump subcontractor direction on the depth in the well to set the pump, the pumping rate, and where to discharge water. The subcontractor must ensure that the pump does not move while the aquifer test is being performed. If pumped groundwater is released to the ground it must be done so away from the area where the aquifer test is being performed. Pumped groundwater that is released to the ground must not act as a source of recharge to the aquifer.

- Measure drawdown over time within the designated observation wells. This may be performed by hand or by using pressure transducers with data loggers. When pressure transducers and data loggers are used, water levels should be checked by hand (manually) to confirm the accuracy of the pressure transducers. Record the manual data on an Aquifer Test Data Form (attached). Report suspect data to the Project Manager (or designee).

- At the completion of the aquifer test, shut down and remove all equipment as appropriate.

- Decontaminate all equipment prior to moving to the next planned well location.

- Properly containerize, label, and store all purged groundwater, decontamination water, and waste, if necessary. Refer to SOP 5.0 – Investigation Derived Waste Disposal for procedures on how to dispose of soil, water, and waste.

- Download the data to a designated data storage device.

11.2 METHODS OF AQUIFER TESTING

This section provides a brief description of the aquifer testing methods that may be used.

11.2.1 Pre-Test Water Level Monitoring

Water level measurements will be collected with an electronic sounder and pressure transducers fitted with data loggers. Prior to using a pressure transducer it should be checked and calibrated. The transducers will be calibrated prior to use by the supplier or AMEC. A Pressure Transducer Calibration Sheet will be completed for each transducer used during the test (attached). If the percent error for measurements made by the transducer is greater than five percent, the data should not be used. The transducer should have sufficient battery life and space in its memory to collect data for the planned duration of the test. The transducer should be synchronized to the internal clock in a laptop computer and set to record pressure levels at a minimum of 1-minute intervals during the pre-test period.

If a pump is to be used during the aquifer test it should be installed in the designated pumping well prior to starting pre-test water level monitoring. A nominal 3-inch diameter Grundfos SQE submersible (or similar) pump attached to 1-inch diameter PVC discharge pipe is typically used for pumping 4-inch diameter monitoring wells. Because extraction and monitoring wells do not typically have large thicknesses of available drawdown in them and are generally completed in aquifers with medium to lower transmissivity, the pump intake may be placed approximately 2 feet above the bottom of the well screen. If there is sufficient sustainable drawdown in the pumping well, the pump intake may be placed above the top of the screen interval. The deciding criterion for setting the pump depth should be whether the well will sustain a pumping water level sufficient to prevent the pump from breaking suction due to excessive drawdown in the well. Generally, pumping rates during a pumping test shouldn't draw down more than approximately 65 to 70 percent of the maximum available drawdown. Clamps should be used to secure the pump at the surface so it doesn't slip during monitoring.

The water level in each well will first be measured using an electronic sounder to an accuracy of +/- 0.01 foot. A sounder will be used for successive measurements in the well for the duration of the test. Pressure transducers will be installed in the wells after initial water level measurements are collected with a sounder. Pressure transducers will be installed in the pumping well and observation wells to a depth greater than the maximum anticipated drawdown within the well. The transducers will be suspended from the top of the well casing using a direct read or wire cable. The cable will be secured to the top of the well casing using methods appropriate for the well head configuration. The transducer must not slip while water pressure measurements are collected. The transducer installed in the pumping well may be placed immediately above the pump but must not be placed deeper than the manufacturer's maximum pressure range. The transducers will be allowed to record pressure in the wells for a minimum of 24 hours to allow the water levels in the wells to equilibrate and establish baseline water level conditions.

Atmospheric pressure data will be collected using a barometric pressure transducer located at or near the pumping well. If an aquifer test is being performed without pumping, the pressure transducer should be located near the middle of the group of wells used during the test. Barometric pressure will be measured using a pressure transducer and the data logger will be programmed at the same interval frequency as that programmed for the water level transducers so that barometric corrections may be applied to the drawdown data, if necessary.

The pre-test water level data recorded by the transducers in the pumping well and observation wells will be downloaded to a laptop computer before starting the aquifer test. After downloading the data, the transducers installed for a slug test in the extraction and observation wells will be set to record water pressure at 1-second intervals (or shorter [e.g., 0.5 seconds] if the transducer is capable of recording less than 1-second intervals). The transducers should be programmed to record water pressure at graduated intervals for step-, constant discharge, and specific capacity tests because of the longer durations of these tests. The graduated intervals may be customized for the particular test based on the estimated or observed drawdown characteristics from recent well purging. If graduated intervals cannot be programmed into the particular data loggers being used, then use 0.5 to 1 second intervals for the first hour of the test. After one hour, change to 30 minute intervals between measurements. After 4 hours, change to 1 hour intervals between measurements to the conclusion of pumping. Restart the measurement cycle at the same time that the pump is turned off. A guideline for frequency of collecting transducer water level measurements is summarized in Table 1 (for step-drawdown, constant discharge, specific capacity, or other long duration tests).

Table 1. Guideline Time Intervals for Measuring Drawdown using a Pressure Transducer for Long Duration Aquifer Tests.

Time Since Start of Pumping (and Time Since Stopping Pump [Recovery])	Time Intervals Between Measurements
0 to 2 minutes	0.5 - 1 seconds
2 to 5 minutes	10 seconds
5 to 15 minutes	1 minute
15 to 60 minutes	5 minutes
60 minutes to 4 hours	30 minutes
4 hours to conclusion	1 hour

11.2.2 Step-Drawdown Test

A step-drawdown aquifer test is performed to estimate the maximum sustainable discharge rate for the pumping well. Aquifer parameters may also be calculated from step-drawdown tests, however, the parameters may possess error because of the relatively shorter duration for the step-drawdown test compared to a longer duration pumping test (e.g., constant discharge test).

Water level measurements will be collected using electric sounders or pressure transducers with a data logger. All data will be recorded for the selected pumping and observation wells.

The pumping phase of the step-drawdown test will consist of the following:

- Pumping the well at successively higher pumping rates (steps) specified by the responsible professional, with an approximate duration of one to four hours per step. The pumping rates will be based on information collected from the well during previous monitoring events or during well installation. As a general guide, 4-steps will be used with the target pumping rates customized for the particular test and aquifer characteristics (e.g., ranging from approximately 1 gallon per minute (gpm), up to 20 gpm). The actual number of steps, pumping rates, and durations for the step test may be adjusted if the targeted pumping rates and durations cannot be achieved in the field. A short pre-test should be conducted to help decide what pumping rates should be used during the step-drawdown test. If a pre-test is conducted, make sure that the water levels in all wells have rebounded to within 95% of the pre-test static water levels. The objective for the step-drawdown test is to pump the extraction well at the highest reasonable flow rate without causing turbulent flow in the well or dropping the water level in the well below the level of the transducer or pump.

- Periodically and at similar times measuring the water levels in the pumped well and observation wells during each step.

- Measuring the instantaneous and cumulative discharge from the pumped well using an in-line flow meter or other appropriate means; and

- Recording the time at which all measurements were taken.

A guideline for frequency of collecting manual water level measurements is summarized in the Table 2. This table should be a guide for all types of aquifer tests that are performed when manually measuring water levels.

Table 2. Guideline Time Intervals for Manually Measuring Drawdown.

Time Since Start of Pumping (and Time Since Stopping Pump [Recovery])	Time Intervals Between Measurements
0 to 2 minutes	15 seconds
2 to 5 minutes	30 seconds
5 to 15 minutes	1 minute
15 to 60 minutes	5 minutes
60 minutes to 4 hours	30 minutes
4 hours to conclusion	1 hour

The pumping rate for each step will be maintained as constant as possible. The rate will be checked periodically (at least hourly) and adjusted if necessary. The accuracy of the flow meter will be checked prior to conducting the test using a graduated container and a stopwatch, or similar method.

The recovery phase of the step-drawdown test begins immediately after the pump is shut off at the completion of the final step of the pumping phase. Recovery water-level measurements will be made periodically in the pumped well and observation wells (use Tables 1 and 2 as guides for measurement frequencies for transducer-based and manually measured water levels, respectively). Water level measurements will conclude when one of the following is satisfied:

- The water level in the pumped well has recovered to within 90 percent of the pre-test level;
- The water level in the pumped well has remained within 5 percent difference over at least a 2-hour period; or

- 24 hours have elapsed since the time of pump shut-off and the water level has not recovered to within 90 percent of the pre-test level.

Following the recovery phase, the pressure transducers will be removed from the test wells. The pressure data measured by each transducer (including the barometric pressure transducer) will be downloaded onto a laptop computer. Each data set will be identified by test phase and well name. The results of the step-drawdown test can be used to assess whether the planned configuration of a constant discharge pumping test is adequate to calculate hydraulic parameters of the aquifer. Modifications to the planned constant discharge test may include the number and location of observation wells, the pumping rate, and the duration of the test.

11.2.3 Constant Discharge Test

The purpose of the constant discharge test is to develop data that may be used for the calculation of hydraulic properties for the aquifer. These properties include transmissivity, hydraulic conductivity, and storage coefficient (confined aquifer) or specific yield (unconfined aquifer). Prior to the constant discharge test, water level measurements will be collected in the pumped well and all observation wells that are to be monitored throughout the duration of the test. Water level measurements will be collected with electric sounders, pressure transducers with a data logger, or a measuring tape. All pre-test water level measurements for the pumping well and observation wells will be recorded for the designated well.

The pumping phase of the constant discharge aquifer test will consist of the following:

- Pumping the well at a constant designated rate;
- Periodically and at similar times measuring the water levels in the pumped well and observation wells during pumping;
- Measuring the instantaneous and cumulative discharge from the pumped well using a flow meter or other appropriate means; and
- Recording the time at which all measurements were taken.

The duration of the pumping phase will be established prior to the start of the aquifer test. Time-drawdown curves for the observation wells may be plotted in the field on semi-logarithmic or logarithmic graph paper or software installed on the laptop computer (e.g. Excel™, or AQTESOLV™) during the pumping phase to evaluate the progress of the test. If the plots indicate steady-state conditions in the aquifer, the test may be ended before its planned conclusion if approval is given by the responsible professional (and approved by the Project

Manager or designee). Likewise, the pumping phase of the test may be extended at the discretion of the responsible professional (and approved by the Project Manager or designee).

The water levels in the pumped well and the observation wells will be measured with transducers and data loggers, if available, and manually on a pre-determined time schedule (see Tables 1 and 2 for guidelines, respectively).

Discharge from the pumped well will be measured using a flow meter and a stopwatch or other appropriate methods. Discharge will be maintained as constant as possible. The discharge rate will be measured and adjusted (if necessary, at 10-minute intervals during the first hour of pumping and 1-hour intervals thereafter). The accuracy of the flow meter will be checked using a graduated container and a stopwatch or similar method prior to starting the test. The rate of discharge, cumulative gallons discharged, and time of measurement will be recorded on the Aquifer Test Data Form.

If pumping should stop (due to mechanical breakdown of generator, pump, etc.) for a period greater than 2 percent of the elapsed pumping time, the test should be postponed and measurement of recovering water levels in the wells started as soon as is practicable. The pumping phase of the test may be resumed when one of the following conditions has been reached:

- The water level in the pumped well has recharged to within 5 percent of the pre-test water level; or
- The well has not been pumped for a period at least equal to the elapsed pumping time of the test before postponement.

Upon completion of the pumping phase of the test, the pump will be shut off. Water level measurements will be taken simultaneously in the pumped well and the observation wells immediately following pump shut-off according to a predetermined schedule (see Tables 1 and 2 for guidelines).

Water level measurements will be concluded when one of the following conditions applies:

- The water level in the pumped well has recovered to within 90 percent of the pre-test water level;

- The water level in the pumped well has remained within 5 percent difference over at least a 2-hour period; or
- 24 hours have elapsed from the time the pump was shut off and the water level has not recovered to within 90 percent of the pre-test level.

Following the recovery phase, the pressure transducers will be removed from the test wells. The pressure data measured by each transducer (including the barometric pressure transducer) will be downloaded onto a laptop computer. Each data set will be identified by test phase and well name.

11.2.4 Slug Tests

Slug tests involve a single well in which the response to an "instantaneous" raising or lowering of the water level is measured. Slug-in and slug-out tests will be performed when conducting conventional slug tests. Slug tests are generally of short duration, usually less than 5 minutes, with the first 30 seconds being most important. As such, measurement of water levels during the test should be measured using a pressure transducer and data logger. If the formation is relatively low yielding, the test period may be longer and manual measurement methods may be used.

At the beginning of a conventional slug test, a known volume of water is either bailed from or added to the well, or a weighted slug of known volume is lowered into or raised from the well. A weighted slug may be constructed with PVC pipe that is filled with sand and capped on both ends. A rope may be used to lower the slug into place. The rope must be secured at the surface to ensure that it does not slip during the test. For the slug-in test, the slug should be installed to a depth of at least two feet below the static water level, if possible. The water level is measured immediately after the slug or water is added (slug-in phase) or removed (slug-out phase). Then the change in water level with time is measured in pre-determined increments typically using an electric sounder and pressure transducers. A schedule guide for collecting manual water level measurements is provided in Table 2. When using transducers with a data logger, the transducers should be programmed to collect water pressure measurements at least once per second (or shorter [e.g., 0.5 seconds] if the transducer is capable of recording less than 1-second intervals) where shorter intervals are more desirable (i.e., quick water level responses in the well when the slug is moved).

The slug-in and slug-out tests will be stopped after the water level has recovered to a minimum of 90 percent of the static water level. After completing the slug-out test, the transducer will be removed and the data it recorded will be downloaded onto a field laptop. Each data set will be identified by test phase and well name.

Over the past ten to fifteen years, new approaches to conduct and analyze slug tests have been developed for formations of relatively higher hydraulic conductivity. A pneumatic slug test consists of pressurizing a well to artificially lower the water in the well instead of removing a slug. The pneumatic test is performed similarly to using a fabricated slug and measuring the rise in water level over time (slug-out test). An apparatus consisting of pipe fittings and a pressure gauge are attached to the well to be tested so that an air tight seal is created. The apparatus may be constructed or purchased as a kit.

The well is pressurized (less than approximately 20 pounds per square inch [psi]). The water level in the well is allowed to equilibrate to the increased pressure and then the pressure is released instantaneously while water levels are rapidly measured over time similar to the procedure outlined previously using a solid slug. Pneumatic tests should be run a minimum of three times per location and at different pressures to test the aquifer and ensure that there are no after effects from the previous test. A minimum of ninety percent recovery should be achieved before starting the next test.

11.2.5 Specific Capacity Tests

A specific capacity test is a constant discharge-constant drawdown pumping test. The purpose of specific capacity testing is to determine the specific capacity of the pumping well and to estimate transmissivity by using an established empirical relationship between specific capacity and transmissivity. These estimates can be used to compare with hydraulic parameters collected during long-term pumping tests or as a preliminary estimate of transmissivity when long-term pumping tests have not been performed.

The practical requirement of the field method is to achieve a stabilized drawdown in the pumping well at a constant pumping rate. The pumping rate should be low enough for the results to be indicative of aquifer properties and not overly influenced by losses due to well efficiency. The stabilized drawdown condition should be achieved at a constant pumping rate for a duration of at least 30 minutes. Water levels will be measured using an electric sounder (with +/- 0.01 foot accuracy) or pressure transducers with a data logger. The pumping rate is measured with a flow meter or using a graduated container and a stopwatch. The cumulative volume pumped is recorded at the time water level measurements are taken. Time is measured in seconds with a stopwatch. Static and pumping water levels, pumping rate and/or cumulative gallons removed, and time at which measurements were taken will be recorded on the Aquifer Test Data Form (attached).

11.3 Revision Log

Revision #	Author	Description of Change (Section #)	Reviewer	Date
00	AC	Drafted initial SOP. Technical Review Reviewed and Finalized	 KP AC	8/26/13 9/12/13 9/25/13

ATTACHMENTS

- Aquifer Test Data Form

AQUIFER TEST DATA

amec

Date ____________ Company performing test ___________________________ Measured by ____

Well No. _______ Distance from pumping well ___________ Type of test ____ Test No. _________

Measuring equipment ____

Time Data					Water Level Data				Discharge Data		
Pump on/Slug in: Date _______ Time _______ (t) Pump off/Slug out: Date _______ Time _______ (t') Duration of Aquifer Test: Pumping ______ Recovery ______					Static water level ________________ Measuring point _________________ Elevation of measuring point ______				How Q measured: _________________ Depth of pump/air line: _________________ Previous pumping? Yes _____ No _____		Comments on factors affecting test data
Date	Clock time	Time since pump started t	Time since pump stopped t'	t/t'	Water level measure ment	Correction or Conversion	Water level	Water level change s or s'	Discharge measure-ment	Rate	

1.0 – ION EXCHANGE BENCH-SCALE TESTING

Purpose and Scope: This document outlines the experimental procedures to be employed in testing the effectiveness of different ion exchange resins for the treatment of mine wastewater from the Rico-Argentine Mine Site. The following procedures for column testing are based on published methods (ASTM D3375 & ASTM D2187). The procedure for isotherm (jar) testing has been adapted from instructions provided by the manufacturer (DOWEX).

1.1 ISOTHERM TESTING

Apparatus: The following equipment will be required to complete the isotherm testing:

- 4, 1-litre beakers per water sample and resin combination
- Bench mixing apparatus
- Nitrile gloves as required
- Temperature probe
- pH meter
- Laboratory containers for sample analysis
- Notebook and spreadsheet software for data recording and analysis

Procedure: The following procedure will be followed in testing each resin and source water combination. All resins will be preconditioned per the manufacturer's specifications.

1. For each resin and source water combination, 4 1-litre beakers will be prepared with labels indicating 15 minutes, 30 minutes, 1.5 hours and 4 hours.
2. Water will be added to the beakers, followed by resin. The ratio of water to resin will be determined by the manufacturer instructions. The resin will be washed and preconditioned per the specifications.
3. The beakers will be placed in a mixing apparatus and mixed continuously at low speed for up to 4 hours.
4. A water sample will be collected from each final solution, preserved appropriately, and submitted for laboratory analysis.
5. Water samples will be monitored for temperature and pH during the experiments. .
6. The above procedure will be repeated for each combination of selected resins and water source.
7. Two control tests will also be performed. A procedural control test will be performed by washing and preconditioning the resin, and performing a test using deionized water. An analytical control test will be performed using mine water without resin, under test conditions. Steps 1 through 5 will be repeated for each control test.

1.2 COLUMN TESTING

Apparatus: The following equipment will be required to complete the column test:

- Nitrile gloves as required
- A transparent, vertically supported column with an inside diameter of 25.4 m (1 in.) and a height of approximately 1500 mm (60 in.).
- Supporting material (glass beads) for the ion exchange resin
- 6-mm tubing
- A peristaltic pump
- 6 6-mm valves to allow for control of flow and backwash
- Deionized water
- Acid reagent, as suggested by the manufacturer
- Laboratory containers for sample analysis
- Temperature probe
- pH meter

Procedure: The following procedure will be followed in testing each resin and water source.

1. The temperature of the source water, deionized water, and resins will be adjusted to ± 5^{o}C from ambient room temperature, as measured at the beginning of the experiment. This temperature will be monitored throughout the test.
2. The column will be held vertically, with the tubing and valves arranged as shown in Fig. 1 below. The glass beads will be added to fill approximately 50mm of the bottom of the column.

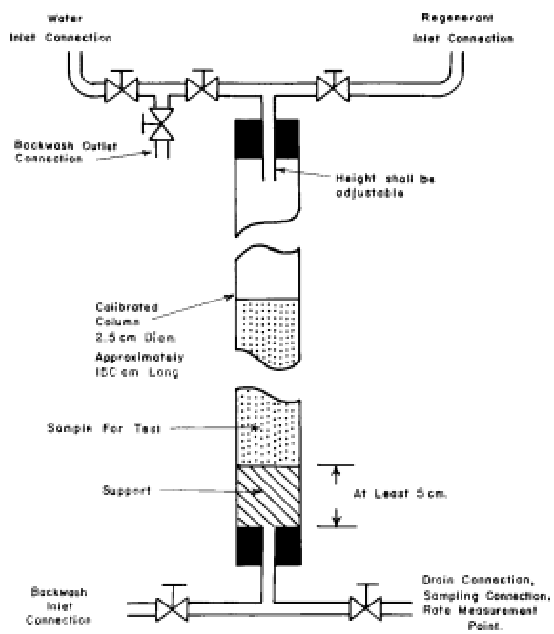


Figure 1: Typical Arrangement of Apparatus for Pretreatment of Ion Exchange Materials

3. The column will be filled half with deionized water. Sufficient resin will be added to create a bed of approximately 750mm above the support material. The height of the resin and support material will be recorded.
4. The column will be backwashed with deionized water for 10 minutes at a flow rate sufficient to cause a 50% expansion in the volume of the bed. If the effluent is not clear after 10 minutes, the backwash will continue at the same rate until clear effluent is obtained.
5. The bed will be allowed to settle. Once the bed has settled, the column will be drained at a rate of 100ml per minute until the water level reaches 20mm above the top of the bed. The bed volume will be recorded.
6. Step 5 will be repeated 3 times, or until the volumes agree within ±5ml. This will be recorded as the bed volume.
7. The column will then be flushed with mine water at a rate of 0.33 ml per minute per ml of resin in the bed. This will be calculated following the determination of bed volume. A liquid head of no less than 50mm will be maintained above the resin bed during the test.
8. An approximate resin exhaustion time will be determined using Purolite's PureDesign simulation software. The breakthrough time estimated by the software will be confirmed using lab results once the test has been completed.
9. Samples will be collected every hour, and pH and temperature measurements will be recorded.
10. A 10 minute backwash will be performed using deionized water, as described in step 4. Only a single backwash will be performed. A regeneration cycle will then be performed by passing an agreed upon eluent through the resin. The respective flow rate and retention time may differ based on manufacturers recommendations. Following completion of the elution, deionized water will be flushed through the bed at a rate of approximately 100ml/minute until regeneration is complete. The resulting wash water will not be analyzed.
11. The type of regenerant and rate will be determined through conversations with the resin manufacturers.
12. Steps 4 through 10 will be repeated once more for a total of 2 regenerations.
13. Hourly samples will be archived in a temperature-controlled environment under proper chain-of-custody procedures. A series of representative samples taken at equal time intervals will be submitted for laboratory analysis, as described in the project scope. These results will be used to confirm the time exhaustion occurred, and further testing can be performed on the archived samples as necessary.
14. Further tests can be performed to determine the effect of different regenerants on resin performance if deemed necessary.
15. The resin will be screened through appropriately sized filtration media following regeneration to determine the volume of fines generated by osmotic shock.

1.3 REVISION LOG

Revision Number	Author	Description of Change (Section number)	Date
0	AMEC	Initial version of SOP 12	June 2013

13.0 – SOIL, ROCK, SEDIMENT, AND MATRIX SAMPLING

Purpose and Scope: The purpose of this document is to provide procedures for collecting representative soil, rock, sediment, and matrix samples for chemical, biological, or physical analyses. It includes preparation, sample collection, and health and safety.

Equipment:

Blue or double bagged ice
Bucket Auger
Camera
Compass
Dip sampler
Discrete depth sampler
Eckman dredge
Extension rods
Hand-Held Global Positioning System (GPS) device
Ice chests
Miscellaneous field equipment
Nylon rope
Ponar dredge
Sample containers (cleaned and provided by laboratory)
Scoop
Sieve
Slide hammer
Spade or shovel
Spatula
Stainless steel, plastic, or other appropriate composition bucket
Survey stakes, flags, or buoys and anchors
Tape Measure
Thin-walled auger
Thin-wall tube auger
Thin-wall tube sampler
Trowel
Tube sampler
T-handle
Waders
Ziploc plastic bags

Documentation: Atlantic Richfield Chain-of-Custody form (COC) or laboratory equivalent
Daily Field Record (DFR)
General Sampling Record
Media Description and Observation Record
GPS Log
Logbook
Maps/plot plan
Photograph Log
Sample Control Log
Sample Labels

13.1 PREPARATION

Set-up and execution of the soil, rock, sediment, and matrix sampling will be performed by appropriately trained field staff under the guidance of a licensed Professional Geologist or Professional Engineer. Prior to conducting the sampling, the following tasks will be completed:

1. Determine the extent of the sampling effort, the sampling methods to be employed, and required equipment and supplies.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment following SOP 4.0 – Equipment Decontamination and ensure that the equipment is in working order.
4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
5. Scout proposed locations to ensure accessibility and sampling feasibility.
6. Use stakes, flags, or buoys to identify and mark all sampling locations. A GPS may be used to document the surface coordinates of the sample location. If required, the proposed locations may be adjusted based onsite access, property boundaries, and obstructions.

13.2 MEDIA SAMPLING METHODS

Soil, rock, sediment, and matrix samples may be recovered using scoop or trowel or hand auger. The method used to collect media samples will depend on the sampling depth, the portion of the media required (surface versus subsurface), the type of sample required (disturbed versus undisturbed), and the media type. All sampling equipment must be decontaminated prior to collecting a sample at each location as described in SOP 4.0 – Equipment Decontamination. Media samples will be collected using the grab, composite, or incremental sampling techniques (SOP 2.0 – Sample Collection Techniques and Data Collection Strategies).

The following sections describe techniques that may be used to collect media samples.

13.2.1 Scoop or Trowel Samplers

A trowel sampler is used to collect shallow media samples, up to 6-inches in depth. A stainless steel or plastic scoop or trowel will be sufficient in most applications. A spade or shovel may be used to collect the sample if the sediment is being collected exclusively for physical property analysis (e.g. grain-size distribution). Metal plated devices should be avoided. The following procedures should be followed when collecting samples with a scoop or a trowel:

1. Use a pre-cleaned stainless steel or plastic scoop or trowel to remove the desired thickness of media from the sampling area.

2. Transfer the sample into an appropriate laboratory-supplied glass or polyethylene jar.

3. Label the container and package sample as described in SOP 1.0 – Field Documentation and Sample Handling.

4. Record sample information on a General Sampling Record and/or on a Media Description and Observation Record (attached).

13.2.2 Hand Auger Samplers

A hand auger fitted with a stainless steel barrel (typically 3 inches in diameter) can be used to collect media samples at the surface up to approximately 10 feet below ground surface if the media is soft enough. The sample barrel is constructed with a cutting shoe, with hard surfacing on it to help with cutting through hard or rocky materials. Use the following procedure to collect media samples with an auger:

1. Insert the auger into the material to be sampled at a 0° to 45° angle from vertical. This orientation minimizes spillage of the sample from the sampler. Extraction of samples may require tilting of the sampler.

2. Rotate the auger once or twice to cut a core of material.

3. Slowly withdraw the auger, making sure that the slot is facing upward.

4. An acetate core may be inserted into the auger prior to sampling. By using this technique, an undisturbed core can be extracted.

5. Transfer the sample into an appropriate laboratory-supplied glass or polyethylene jar or pre-cleaned stainless steel sleeve and seal the end(s). If collecting a sample in a stainless steel sleeve, the sampler will seal the ends with a sheet of Teflon and a cap on both ends of the tube. The caps will be taped in place using silicone tape to preserve media moisture.

6. Label the container and package sample as described in SOP 1.0 – Field Documentation and Sample Handling.

7. Record sample information on a General Sampling Record and/or on a Media Description and Observation Record (attached).

13.2.3 AUGERS AND THIN-WALL TUBE SAMPLERS

This system uses an auger, a series of extension rods, “T” handle, and a thin-wall tube sampler. The auger bores a hole to a desired sampling depth and then is withdrawn. The auger tip is then replaced with a tube core sampler, lowered down the borehole, and driven into the media at the completion depth. The core is then withdrawn and sample collected.

Follow these procedures to collect sediment samples with a hand auger:

1. Attach the auger bit to a drill extension rod, and then attach the “T” handle to the drill extension rod.

2. Clear the area to be sampled of any surface debris.

3. Begin auguring, periodically removing any accumulated media from the auger bucket.

4. After reaching the desired depth, slowly and carefully remove the auger from the borehole.

5. Remove auger tip from drill rods and replace with a pre-cleaned thin –wall tube sampler. Install the proper cutting tip.

6. Carefully lower the tube sampler down the borehole. Gradually force the tube sampler into the media. Care should be taken to avoid scraping the borehole sides. Also avoid hammering of the drill rods to facilitate coring, since the vibrations may cause the borehole walls to collapse.

7. Remove the tube sampler and unscrew the drill rods.

8. Remove the cutting tip and remove the core from the device.

9. Discard the top of the core (approximately 1 inch), as this represents the material collected by the tube sampler before penetration of the layer of concern.

10. Transfer the sample into an appropriate laboratory-supplied sampling container or pre-cleaned stainless steel sleeve and seal the end(s).

11. Label the container and package sample as described in SOP 1.0 – Field Documentation and Sample Handling.

12. Record sample information on a General Sampling Record and/or on a Media Description and Observation Record (attached).

13.3 Bulk Media Sampling

Bulk soil samples for some physical and mineralogical tests may be collected from test pits and soil borings. Samples will be collected from test pits less than 5-feet deep from the wall of the pit with a stainless steel or plastic trowel. In test pits deeper than 5-feet, samples will be collected out of the backhoe bucket. Bulk samples from soil borings will be collected from the cuttings produced during drilling or retrieved from a sampler.

Samples of sand, silt, and clay-size material will be collected into gallon-sized re-sealable plastic bags (minimum) or in stainless steel sleeves. Coarse-grained gravels and cobbles will be collected into 5-gallon buckets. In general, the size of the bulk sample will be at least 10 times greater than the size of the largest class or material.

13.4 Composite Media Sampling

Media samples are composited to combine media from two or more sampling locations so that the composite that is submitted for analysis is representative of the entire mass of media sampled. Samples can be composited in the laboratory or in the field.

Individual samples to be composited will be identified on their labels. Samples to be composited in the laboratory will be identified clearly on the COC and on the sample control log. In general, compositing consists of the following steps:

- Take an approximately equal in volume sub-sample from each sampling location to be composited. The size of each sub-sample should be chosen based on the final sample volume and the amount of material available;

- Combine and homogenize the sub-samples in a Stainless steel, plastic, or other appropriate composition bucket

- Use a stainless steel or plastic scoop or trowel to break up cohesive materials.
- Mix composite sample until it appears to be homogeneous.
- Extract sample from the homogenized media using a stainless steel or plastic scoop or trowel and place sample into a laboratory supplied sampling container.

Label the container and document the sample as described in SOP 1.0 – Field Documentation and Sample Handling. The sampler must identify the sample as a composite and identify the number and locations of samples that were composited on the DFR and sample control log.

13.5 PHYSICAL DESCRIPTION OF SAMPLE MEDIA

This section presents the descriptive terms and general procedures that can be used to describe soil, rock, sediment, and matrix samples. Physical description of sample media can include color, moisture content, percent distribution of coarse and fined grained material, and odor (if present).

13.5.1 Color

Indicate the sample color using a Munsell color chart. The color should be recorded immediately after the sample has been collected.

13.5.2 Moisture Content

Indicate the moisture in the sample. The moisture should be assessed immediately after the sample has been collected. Terms that can be used to describe moisture content are described below.

- Dry - Absence of moisture, dusty, dry to touch
- Moist - Damp but no visible water
- Wet or Saturated - Visible free water, usually soil is below water table

13.5.3 Percent Distribution of Coarse- and Fine-Grained Material

Indicate the approximate amount of coarse and fine grained material in the sample by percent volume. Include the grain size in the description and angularity or coarse-grained media. Terms that can be used to describe grain size or angularity of coarse-grained particles are presented below.

Grain Size

- Boulders - Larger than basketball-sized
- Cobbles - Fist-sized to basketball-sized
- Coarse Gravel -Thumb-sized to fist-sized
- Fine Gravel - Pea-sized to thumb-sized
- Coarse Sand - Rock salt-sized to pea-sized
- Medium Sand - Sugar-sized to rock salt-sized
- Fine Sand - Flour-sized to sugar-sized
- Fines - Flour sized and smaller
- Grain Size

Angularity- Coarse-Grained Particles

- Angular - Particles have sharp edges and relatively plane sides with unpolished surfaces
- Subangular - Particles are similar to angular description but have rounded edges
- Subrounded - Particles have nearly plane sides but have well-rounded corners and edges
- Rounded - Particles have smoothly curved sides and no edges

13.5.4 Odor

Indicate if an odor is present.

13.6 Additional Sampling Methods

The selection of procedures presented above is not all inclusive of the media sampling devices that may be used at the site. The use of additional or alternative sampling devices may be required to adequately characterize the site.

13.6 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
0	ARC	Create SOP 13, Soil, Rock, Sediment, and Matrix Sampling Record	7/1/13	LL 7/2/13

ATTACHMENT

- Soil, Rock, Sediment , and Matrix Sampling Record

SOIL, ROCK, SEDIMENT, AND MATRIX SAMPLING RECORD

Project and Task No.: ______________________________

Project Name: ______________________________

Task Name: ______________________________

Sampled By: ______________________________

Samplers Signature: ______________________________

Sampling Location: ______________________________

Source of Media: ______________________________

Method of Sampling[1]: ______________________________

Sample Depth: ______________________________

Sample Type[2]: ______________________________

Photo Document[3]: ______________________________

Sample ID: ______________________________

Sample Date: ______________________________

Sample Time: ______________________________

Sample Size: ______________________________

Color of Media: ______________________________

Percentage of Coarse Grained Media[4]: ________________

Percentage of Fine Grained Media[4]: ________________

Estimate Average Particle Size: ________________

Moisture Content[5]: ______________________________

Odor (if present): ______________________________

Additional comments or observations:

1. Sampling methods include: scoop, trowel, or auger. Include material type (i.e. plastic, stainless steel, etc.).
2. Sample types include: discrete or composite. If composite sample is collected, include number of locations and composited sample size.
3. Photo document sample and sampling location/s and list photos taken on a Photo Log.
4. Include grain size and angularity of coarse-grained media.
5. Moisture content described as dry, moist, or saturated.

14.0 – CONTINUOUS WATER LEVEL MONITORING

Purpose and Scope: The purpose of this document is to present procedures for collecting continuous water level measurements in monitoring wells, piezometers, ponds, and surface water flow measurement stations using pressure transducers. It includes a discussion on procedures for programming and acquiring data from the data loggers as well as general maintenance activities that will be performed.

Equipment:

Barometric pressure transducer(s) fitted with a data logger
Communication cables
Desiccant packets for water level instruments (if required)
Distilled water
Electric sounder
End caps for hanging transducer without direct read capabilities
Field laptop computer loaded with MS Excel™ and manufacturers software for communicating with transducer (i.e. Solinst Levelogger Series Software, In-Situ WinSitu Software)
Computer software for communication with transducer
Lithium ion batteries
Liquinox solution
Manufacturers data downloading device (i.e. Solinst Leveloader, In-Situ Rugged Reader)
Miscellaneous hand tools:
- Socket for flush mounted wells (i.e. ¾” or 15/16”)
- Cutting shears
- Spare combination locks
- Christie box opening tool
- Screwdrivers

Paper towels
Vented or non-vented direct-read cable
Safety equipment (Level D PPE, nitrile gloves)
Spray water bottles
Stainless steel cable (uncoated, 1/16” diameter)
Tape measure (subdivided into tenths of feet)
Water pressure transducer(s) fitted with a data logger

Documentation:

Daily Field Record (DFR)
In-Situ Multi Parameter TROLL 9500 Operator’s Manual
In-Situ Level TROLL 500 Operator’s Manual
Maps/plot plan
Pressure Transducer Calibration Sheet (attached)
Transducer Setup and Download Form (attached)
Solinst Levelogger User Guide
Solinst Series Levelogger Quick Start Guide

This Standard Operating Procedure (SOP) describes the general methodology for the operation of pressure transducers used at the site to measure water levels including but not limited to mine shafts, monitoring wells, monitoring ports, ponds, or wetlands. This SOP describes the procedures for the operation of pressure transducers. Manufacturer user manuals shall be reviewed for specific operational procedures and calibration requirements for each type of pressure transducer used prior to operation.

All field measurements of water will be performed by appropriately trained field staff under the direct supervision of a Professional Geologist or Professional Engineer.

14.1 EQUIPMENT

Review the equipment list and carry the correct tools for the tasks to be performed.

There are two different types of pressure transducers that are currently used at the Rico Mine Site (Site). The first type is an absolute pressure transducer which is a non-vented device and data must be corrected to account for changes in atmospheric pressure, as necessary. The second type is equipped with a vented cable that compensates for changes in atmospheric pressure.

The pressure transducers that are currently used at the site are:

- Solinst Levelogger Model 3001 (non-vented).
- In-Situ Multi Parameter TROLL 9500 equipped with a pressure transducer (TROLL 9500; non-vented / vented)
- In-Situ Level TROLL 500 (non-vented / vented).

Similar pressure transducers may be used as long as they are programmed and operated consistent with their specific manufacturer's user manual.

A barometric pressure transducer fitted with a data logger (e.g., Solinist 3001 Barologger [Solinist Barologger]) can be used to measure changes in atmospheric pressure conditions. The data collected by the barometric pressure transducer can be used to compensate water level readings recorded by non-vented continuous water level monitoring devices. However, if the pressure transducer is used for a short term test (i.e., less than 30 minutes for a slug test), measurements of barometric pressure are not necessary because it is assumed that changes in barometric pressure will be insignificant during the duration of the test and will not affect pressure measurements. As an additional practice, do not perform a slug test while a weather front is passing through the area because rapid barometric pressure changes may occur.

The TROLL 9500 and Level TROLL 500 currently used at the Site are equipped with vented cables and do not require barometric compensation. However, the In-Situ pressure transducers can be equipped with non-vented cables. Prior to use of any pressure transducer, the applicable user manual must be consulted to verify proper operation and setup of the pressure transducer.

14.2 SOLINST LEVELOGGER PROCEDURES

The following subsections describe the procedures for calibration, general setup, installation, data download, and maintenance for the Solinst Levelogger and Barologger.

14.2.1 Solinst Levelogger Calibration Check

Each transducer must have a calibration check performed on it in accordance with manufacturer’s directions before it is installed in a monitoring location. Complete the attached Pressure Transducer Calibration Sheet. Sheets for electronic or manual calculations of the percent error of measurements at prescribed water column height are provided (attached). The transducer should be accurate to 5 percent difference between transducer and manual measurements. If the error is greater than 5 percent, the transducer should not be used.

14.2.2 Solinst Levelogger Software Installation and Transducer Setup Software Installation

The Solinst 3001 Levelogger series software application program, compatible with the 3001 Levelogger and Barologger, must first be installed on the laptop being used for downloading data from the Solinst transducers. If software installation is required, use the instruction presented in the Solinst Levelogger User Guide and the Levelogger Series Quick Start Guide. Keep a copy of the installation software file in the Lab in the Former Lime Plant building.

A Solinst Leveloader can also be used to communicate and download data from the Solinst transducers. The Solinst Leveloader is a portable handheld device that can be used for downloading data and configuring transducers. Refer to the Leveloader User Guide for additional information.

<u>Device Connection</u>

Once the Solinst Levelogger application is installed on the laptop computer, a connection to the data logger can be made to set up the transducer and/or download data. The connection between the Solinst Levelogger and the laptop computer is through a USB cable connected to an optical reader. Refer to the Solinst Levelogger User Guide for additional instructions on the connection steps.

Main Levelogger Software Window

The main Levelogger software window is where the status and option menus are accessed. The functions and information displayed on the main menu screen are discussed in the Levelogger User Guide.

General Transducer Setup

From the main software window the data logger settings, time, sampling mode, and start and stop times are set. See the Levelogger User Manual for screen shots and additional information on set-up procedures. Each Solinst Levelogger will be programmed to include the following information:

- Data logger settings: Enter the monitoring location identification (i.e., well, piezometer, monitoring port, or flow measurement station name). The Project ID "Rico" should also be entered.

- Time: The Data logger Time section provides the controls for setting the data logger clock. The data logger clock should be synchronized to the computer clock. To do so, click "Synchronize" to set the time in the data logger so that it matches the laptop time.

- Sampling mode: For logging at a specific time interval, the data logger sampling mode should be set to linear. Sample intervals may vary depending on the intended use of the transducer. The intended use and sample interval of the transducer should be discussed with the Project Manager or designee prior to setup and installation. Start and Stop Times: Either a Future Start or Future Stop shall be entered. The "Future Start" shall be set at the beginning of the hour (i.e. time = 17:00:00 [hours]) such that it measures the water level simultaneously with transducers installed in other monitoring points with the same purpose.

The main software window has other features which may be used depending on the intended transducer use. See the Levelogger User Guide for additional details.

14.2.3 Solinst Barologger

A Solinst Barologger should be installed at one location to collect measurements of atmospheric pressure changes over time. Data collected by the barologger will be used to perform a barometric pressure compensation calculation for transducers installed in monitoring points without vented cables. The barologger is set-up similarly to the Levelogger as described in Section 14.2.2; refer to the Levelogger User Guide for additional details.

14.2.4 Solinst Transducer Installation

The Solinst transducers are rated for a particular water pressure range. The transducers should not be installed to a depth in the water column that exceeds the maximum allowable pressure tolerance of the device. Refer to the label on the transducer and the Levelogger User Guide for the appropriate water pressure operating range for the transducer.

Lower the transducer to the selected depth in the monitoring point. Use care when lowering the transducer into the monitoring point so as not to damage it during installation. In general, the transducer should not be placed in the bottom of the monitoring point (i.e., the end cap) as sediment and debris can collect in the bottom of the monitoring point and potentially cause damage to the transducer. However, in certain cases (for example, in a dry well or piezometer) it may be necessary to place the transducer very near the bottom of the monitoring point to detect small fluctuations in groundwater levels. In these cases, install the transducer approximately 3 to 5 inches above the bottom of the monitoring point. The intent is to keep the transducer off the bottom but very near the bottom of the perforations in the monitoring point. That way, if water enters the monitoring point, it should be detected by the transducer.

Solinst Leveloggers can be installed with a 1/16-inch, stainless steel suspension cable or a direct read cable. The cable should be of sufficient length to allow the transducer to be suspended below the lowest anticipated water level. For monitoring wells and piezometers, the top of the suspension cable should be secured to the underside of the well cap. For flow measurement stations with direct read cables, the cable end should be secured to a stand or conduit pipe that extends to an easily accessible location (i.e. stream bank).

14.2.5 Solinst Transducer Data Download

Use care when removing the transducer from the monitoring point (if required for communication with the device) so as not to damage it. The suspension cable used to hold the transducer in place should be gathered on a reel to avoid tangling and exposing it to impacted materials on the ground surface.

Collect a manual water level measurement during the data downloading process. Record the water level and document transducer download information on the Transducer Setup and Download Form.

If the Levelogger is not collected to a direct read cable, the transducer will have to be pulled to the surface during the data download process. Connect the transducer to the laptop computer (or Leveloader, as applicable) being used for data downloads via the communication cable. From the main software window, stop logging by clicking the red “x” button. **Do not click start**

until all the data have been downloaded because starting again begins a new recording session and clears previously stored data readings.

Click the Data Control tab. From the Data Control tab, click the download button (a downward pointing arrow in the upper right corner). Select All Data when downloading the data. The program will download all of the data from the current logging session into an ".xle" file. The file should be saved and named using the following convention: location_test type_date. For example: 130919_SSFWMP01_slugin01.xle. Once the ".xle" file has been saved, it shall be exported to a ".csv" file by clicking File, then Export, and then Data. The ".csv" file should be given the same name as the ".xle" file.

After the data have been downloaded, the transducers may be restarted if additional data are required at the monitoring location. If more data are required, set the "Future Start" start time and follow the steps described in the Levelogger User Guide. Follow the instructions described in Section 14.2.4 to place the transducer back in the monitoring location.

After the data have been downloaded, named, and saved, the data logger history should be cleared to prepare it for future recordings. Assure that the data have been downloaded completely (data range and frequency are correct) and that the data file is viable (can be opened) prior to deleting from the data logger memory. If the data collection frequency needs revision, make sure to note this and perform the revision before reinstalling the transducer into the well. Document changes on the Transducer Setup and Download Form.

As previously mentioned in Section 14.2.2, a Solinst Leveloader can also be used to communicate and download data from the Solinst transducers. Refer to the Leveloader User Guide for additional information.

14.2.6 Solinst Transducer Maintenance

Inspections shall be conducted monthly during the field season and at least once during the winter. Transducer inspection and maintenance information shall be documented on the Transducer Setup and Download Form. Inspections will be performed during data download activities as follows:

- During all inspections, inspect the suspension cable and the device for signs of damage or wear. If the cable or transducer has been damaged or is worn it should be repaired or replaced before reinstallation into the monitoring point. Notify the Field Coordinator if a transducer requires repair or replacement.
- At the start of the field season, the length of cable or direct read cable should be measured.

14.3 IN-SITU WATER LEVEL INSTRUMENT – TROLL 9000 MP

The following subsections describe the procedures for calibration, general setup, installation, data download, and maintenance of the In-Situ Water Level Instrument pressure transducer. In-Situ water level instruments are rated for a particular water pressure range, and should not be installed to a depth in the water column that exceeds the maximum allowable pressure tolerance of the device. The processes below are intended for a TROLL 9000 MP sonde, specifically, the Multi-Paramter TROLL 9500 model. When possible, use a vented direct read cable when installing the TROLL 9500. This will allow the tool to be vented to the atmosphere and the data will not need barometric correction.

14.3.1 Troll 9500 Instrument Calibration Check

Each transducer must have a calibration check performed on it in accordance with manufacturer's directions before it is installed in a monitoring location. Complete the attached Pressure Transducer Calibration Sheet. Sheets for electronic or manual calculations of the percent error of measurements at prescribed water column height are provided (attached). The transducer should be accurate to 5 percent difference between transducer and manual measurements. If the error is greater than 5 percent, the transducer should not be used.

14.3.2 Troll 9500 Instrument Software Installation and Transducer Setup

Software Installation

The In-Situ Win-Situ4 and Pocket-Situ software application programs, compatible with the In-Situ TROLL 9000 MP series sonde, must first be installed on the laptop or hand held device being used for downloading data from the sonde. If software installation is required, use the instructions in the Win-Situ4 User's Guide with Pocket-Situ and TROLL 9500 Operator's Manual. Keep a copy of the installation software in the Lab in the Former Lime Plant building.

An In-Situ RuggedReader, or a hand held device loaded with Pocket-Situ, can also be used to communicate and download data from the In-Situ TROLL 9000 MP series sonde. The In-Situ Rugged Reader is a portable handheld device that can be used for downloading data and configuring transducers.

Device Connection

Once the Win-Situ4 or Pocket-Situ application is installed on the laptop computer, a connection to the sonde can be made to set up the sonde and/or download data. The connection between the TROLL 9000 series and the laptop computer is through a USB cable connected to a quick connect direct read cable. Refer to the Win-Situ4 User's Guide with Pocket-Situ and/or TROLL 9500 Operator's Manual for additional instructions on the connection steps.

Win-Situ Software Window

The main Win-Situ4 software window is where the status, option menus, and navigation window are accessed. The functions and information displayed on the main menu screen are discussed in the Win-Situ4 User's Guide with Pocket-Situ and TROLL 9500 Operator's Manual.

General Transducer Setup

The data logger settings, time, device nodes, and start and stop times are set from the main software window. See the Win-Situ4 User's Guide with Pocket-Situ for screen shots and additional information on setup procedures. Each TROLL 9500 will be programmed to include the following information:

- Data logger settings: Enter the monitoring location identification (i.e., well, piezometer, monitoring port, or flow measurement station name). The Project ID "Rico" should also be entered. If the TROLL 9500 does not automatically connect, click on the COM port in the Navigation Window, then in the Main Window, click on "Find", if the TROLL 9500 is not found, refer to the User's Manual for troubleshooting.

- Time: The User's Manual and TROLL 9500 Operator's Manual provides steps for synchronizing the TROLL 9500 with the time on the laptop. In the navigation window, single-click on the device to highlight it. Then, in the main window click on *Edit.* In the Device Wizard, select *Clock. Then,* select *Synchronize Device to Computer Clock*.

- Set up a Test: With the TROLL 9500 connected to the computer, in the Navigation Window, click on *Tests.* Then, click *Add.* Select which parameters will be logged. For logging at a specific time interval, the data logger sampling mode should be set to linear. Sample intervals may vary depending on the intended use of the transducer. The intended use, parameters of interest and sample interval of the transducer should be discussed with the Project Manager or designee prior to setup and installation.

- Parameters: Parameters recorded by the TROLL 9500 may vary depending on the data quality objectives of the task.

    - A calibration check schedule should be determined for the sonde prior to installation. Refer to the Multi-Parameter TROLL 9500 Owner's Manual for descriptions of calibration methods.

- Pressure Sensor: Refer to the Multi-Parameter TROLL 9500 Owner's Manual for setup. The reference point from which water levels are taken should be discussed with Project Manager or designee. TROLL 9500 is capable of recording water level as pressure head, depth, or level – surface. Typically, the pressure transducer should be programmed to measure depth for applications at the site. In order to program the transducer to measure depth, the following items must be programmed to properly convert pressure readings into water depth.

- Program Specific Gravity of the source water where water depth is to be measured. If specific gravity of source water is unknown, select 1.0.
- Program altitude of the site. The approximate altitude of the town of Rico, Colorado is 8,825 feet above mean sea level. If the exact altitude of the monitoring location is unknown, the Rico altitude will be entered as the site altitude.
- Program latitude of the site. The approximate latitude of the town of Rico, Colorado is 37.69° North.

- Scheduled Start Time: A Scheduled Start shall be entered. The “Scheduled Start” shall be set at the beginning of the hour (i.e. time = 17:00:00 [hours]) such that it measures the water level simultaneously with transducers installed in other monitoring points with the same purpose.
- Profiling: The TROLL 9500 is capable of conducting vertical profiles. To start a Profile, select *Parameters* in the Navigation Window, select *Profiler*. Tests and Profiles can be run concurrently. Refer to the TROLL 9500 Owner’s Manual for set up.

14.3.3 TROLL 9500 Transducer Installation

The TROLL 9500 transducers are rated for a particular water pressure range. The transducers should not be installed to a depth in the water column that exceeds the maximum allowable pressure tolerance of the device. Refer to the label on the transducer for the appropriate water pressure operating range for the transducer.

Lower the transducer to the selected depth in the monitoring point. Use care when lowering the transducer into the monitoring point so as not to damage it during installation. In general, the transducer should not be placed in the bottom of the monitoring point (i.e., the end cap) as sediment and debris can collect in the bottom of the monitoring point and potentially cause damage to the transducer. However, in certain cases (for example, in a dry well or piezometer) it may be necessary to place the transducer near the bottom of the monitoring point to detect small fluctuations in groundwater levels. In these cases, install the transducer approximately 3 to 5 inches above the bottom of the monitoring point. The intent is to keep the transducer off the bottom but very near the bottom of the perforations in the monitoring point. That way, if water enters the monitoring point, it should be detected by the transducer.

The cable should be of sufficient length to allow the transducer to be suspended below the lowest anticipated water level. For monitoring wells and piezometers, the top of the suspension cable should be secured to the underside of the well cap. For flow measurement stations with direct read cables, the cable end should be secured to a stand or conduit pipe that extends to an easily accessible location (i.e., stream bank).

14.3.4 TROLL 9500 Transducer Data Download

TROLL 9500 is equipped with a direct read cable and removal of the pressure transducer to download the data is not necessary. Use care when removing the transducer from the monitoring point (if required for communication with the device) so as not to damage it.

To extract data from the TROLL 9500, connect computer with Win-Situ4 to the TROLL 9500, select the test, and click *Extract*, select *View* to observe downloaded data, and select *File* and save data file as a .csv file. Use the filename convention described in Section 14.2.5.

Collect a manual water level measurement during the data downloading process. Record the water level and document transducer download information on the Transducer Setup and Download Form.

After the data have been downloaded, named, and saved, the data logger history should be cleared for the next logging period. Assure that the data have been downloaded completely (data range and frequency are correct) and that the data file is viable (can be opened) prior to deleting the data logger memory. If the data collection frequency needs revision, make sure to note this and perform the revision. Document changes on the Transducer Setup and Download Form.

14.3.5 TROLL 9500 Transducer Maintenance

Inspections shall be conducted monthly during the field season and at least once during the winter. Transducer inspection and maintenance information shall be documented on the Transducer Setup and Download Form. Inspections will be performed during data download activities as follows:

- During all inspections, inspect the suspension cable and the device for signs of damage or wear. If the cable or transducer has been damaged or is worn, it should be repaired or replaced before reinstallation into the monitoring point. Notify the Field Coordinator if a transducer requires repair or replacement.
- At the start of the field season, the length of cable or direct read cable should be measured.

14.4 IN-SITU WATER LEVEL INSTRUMENT – TROLL 500

The following subsections describe the procedures for calibration, general setup, installation, data download, and maintenance of the In-Situ Troll 500 Water Level Instrument pressure transducer. In-Situ water level instruments are rated for a particular water pressure range, and should not be installed to a depth in the water column that exceeds the maximum allowable pressure tolerance of the device. When possible, use a vented direct read cable when installing the TROLL 500. This will allow the tool to be vented to the atmosphere and the data will not need barometric correction.

14.4.1 Level TROLL 500 Instrument Calibration Check

Each transducer must have a calibration check performed on it in accordance with manufacturer's directions before it is installed in a monitoring location. Complete the attached Pressure Transducer Calibration Sheet. Sheets for electronic or manual calculations of the percent error of measurements at prescribed water column height are provided (attached). The transducer should be accurate to 5 percent difference between transducer and manual measurements. If the error is greater than 5 percent, the transducer should not be used.

14.4.2 Level TROLL 500 Instrument Software Installation and Transducer Setup

Software Installation

The In-Situ Win-Situ5 and Pocket-Situ software application programs, compatible with the In-Situ Level TROLL 500 water level instrument, must first be installed on the laptop or hand held device being used for downloading data from the sonde. If software installation is required, use the instruction presented in the Win-Situ5 User's Guide with Pocket-Situ and Level TROLL Operator's Manual. Keep a copy of the installation software in the Lab in the Former Lime Plant building.

An In-Situ RuggedReader, or a hand held device loaded with Pocket-Situ, can also be used to communicate and download data from the In-Situ Level TROLL 500. The In-Situ Rugged Reader is a portable handheld device that can be used for downloading data and configuring transducers.

Device Connection

Once the Win-Situ5 or Pocket-Situ application is installed on the laptop computer a connection to the sonde can be made to setup the sonde and/or download data. The connection between the Level TROLL 500 and the laptop computer is through a USB cable connected to a quick connect direct read cable. Refer to the Win-Situ5 User's Guide with Pocket-Situ and/or Level TROLL Operator's Manual for additional instructions on the connection steps.

Win-Situ Software Window

The main Win-Situ5 software window is where the status, option menus and navigation window are accessed. The functions and information displayed on the main menu screen are discussed in the Win-Situ5 User's Guide with Level TROLL 500 Operator's Manual.

General Transducer Setup

The data logger settings, time, device nodes, and start and stop times are set from the main software window. See the Win-Situ5 User's Guide with Pocket-Situ for screen shots and additional information on set-up procedures. Each Level TROLL 500 will be programmed to include the following information:

- Data logger settings: Enter the monitoring location identification (i.e., well, piezometer, monitoring port, or flow measurement station name). The Project ID "Rico" should also be entered. If the Level TROLL 500 does not automatically connect, click on the COM port in the Navigation Window. Then, in the Main Window, click on "Find." If the Level TROLL 500 is not found, refer to the User's Manual for troubleshooting.

- Time: The Level TROLL 500 Operator's Manual provides steps for synchronizing the Level TROLL 500 with the time on the laptop. In the navigation window, single-click on the device to highlight it. Then, in the main window, click on *Edit.* In the Device Wizard, select *Clock.* Select *Synchronize Device to Computer Clock*.

- Set up a Test: With the Level TROLL 500 connected to the computer, in the Navigation Window, click on *Logging Tab. Then,* click *New.* The Logging Setup Wizard will prompt the user through the data logging configuration. For logging at a specific time interval, the data logger sampling mode should be set to linear. Sample intervals may vary depending on the intended use of the transducer. The intended use, parameters of interest, and sample interval of the transducer should be discussed with the Project Manager or designee prior to setup and installation.

- A calibration schedule should be determined for the sonde prior to installation. Refer to Level TROLL 500 Owner's Manual for descriptions of calibration methods.

- Pressure Sensor: Refer to the Level TROLL 500 Owner's Manual for set up. The reference point from which water levels are taken should be discussed with Project Manager or designee. TROLL 500 is capable of recording water level as pressure head, depth, or level – surface. Typically, the pressure transducer should be programmed to measure depth for applications at the site. In order to program the transducer to measure depth, the following items must be programmed to properly convert pressure readings into water depth.

    - Program Specific Gravity of the source water where water depth is to be measured. If specific gravity of source water is unknown, select 1.0.

  - Program altitude of the site. The approximate altitude of the town of Rico, Colorado is 8,825 feet above mean sea level. If the exact altitude of monitoring location is unknown, the Rico altitude will be entered as the site altitude.
  - Program latitude of the site. The approximate latitude of the town of Rico, Colorado is 37.69° North.

- Scheduled Start Time: A Scheduled Start shall be entered. The “Scheduled Start” shall be set at the beginning of the hour (i.e. time = 17:00:00 [hours]) such that it measures the water level simultaneously with transducers installed in other monitoring points with the same purpose.

14.4.3 TROLL 500 Transducer Installation

The TROLL 500 transducers are rated for a particular water pressure range. The transducers should not be installed to a depth in the water column that exceeds the maximum allowable pressure tolerance of the device. Refer to the label on the transducer for the appropriate water pressure operating range for the transducer.

Lower the transducer to the selected depth in the monitoring point. Use care when lowering the transducer into the monitoring point so as not to damage it during installation. In general, the transducer should not be placed in the bottom of the monitoring point (i.e., the end cap) as sediment and debris can collect in the bottom of the monitoring point and potentially cause damage to the transducer. However, in certain cases (for example, in a dry well or piezometer) it may be necessary to place the transducer near the bottom of the monitoring point to detect small fluctuations in groundwater levels. In these cases, install the transducer approximately 3 to 5 inches above the bottom of the monitoring point. The intent is to keep the transducer off the bottom but very near the bottom of the perforations in the monitoring point. That way, if water enters the monitoring point, it should be detected by the transducer.

The cable should be of sufficient length to allow the transducer to be suspended below the lowest anticipated water level. For monitoring wells and piezometers, the top of the suspension cable should be secured to the underside of the well cap. For flow measurement stations with direct read cables, the cable end should be secured to a stand or conduit pipe that extends to an easily accessible location (i.e., stream bank).

14.4.4 Level TROLL 500 Transducer Data Download

Level TROLL 500 is equipped with a direct read cable and removal of the pressure transducer to download the data is not necessary. Use care when removing the transducer from the monitoring point (if required for communication with the device) so as not to damage it.

To extract data from the Level TROLL 500, connect computer with Win-Situ5 to the Level TROLL 500, select the *Download* button, go to the *Data* tab and select downloaded data file, and select *File and* save data file as a .csv file. Use the filename convention described in Section 14.2.5.

Collect a manual water level measurement during the data downloading process. Record the water level and document transducer download information on the Transducer Setup and Download Form.

After the data have been downloaded, named, and saved, the data logger history should be cleared for the next logging period. Assure that the data have been downloaded completely (data range and frequency are correct) and that the data file is viable (can be opened) prior to deleting from the data logger memory. If the data collection frequency needs revision, make sure to note this and perform the revision. Document changes on the Transducer Setup and Download Form.

14.4.5 Level TROLL 500 Transducer Maintenance

Inspections shall be conducted monthly during the field season and at least once during the winter. Transducer inspection and maintenance information shall be documented on the Transducer Setup and Download Form. Inspections will be performed during data download activities as follows:

- During all inspections, inspect the suspension cable and the device for signs of damage or wear. If the cable or transducer has been damaged or is worn, it should be repaired or replaced before reinstallation into the monitoring point. Notify the Field Coordinator if a transducer requires repair or replacement.
- At the start of the field season, the length of cable or direct read cable should be measured.

14. 5 DATA MANAGEMENT

After downloading, the transducer data files should be saved on the Rico Site external hard drive and emailed to the appropriate project staff for barometric compensation (if applicable), data review, and verification. Field personnel downloading transducer data should coordinate with the Field Manager to determine who is responsible for data review and verification.

14.6 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
00	KW/ARC	KW prepares SOP, AC reviews and adds information regarding the setup of Level Troll 500	9/11/13	
		Technical Review	9/19/13	KEP
		Reviewed and Finalized	9/24/13	AC

ATTACHMENT

- Transducer Setup and Download Form

PRESSURE TRANSDUCER CALIBRATION SHEET

amec

Transducer Data and Status Check (Completed By: ______________)

Date of Calibration: ______________ **Date Arrive/ Return:** ______________

Equipment Type: ______________ **Equipment Manufacture:** ______________

Serial No.: ______________ **Cable Length / Type (ft):** ______________

Press. Rating (PSI): ______________ **Precision Rating (ft):** ______________

Clock Sync: ______________ **Commun. Cable:** ______________

Manufac. Date: ______________ **Calibration Date:** ______________

Storage (bytes): ______________ **Storage Available (%):** ______________

Battery Install Date: ______________ **Battery Remain (%):** ______________

Other: ______________

External Datalogger Transducers (Completed By: ______________)

Datalogger SN: ______________ **Datalogger ID:** ______________

Channel No.: ______________ **Linearity:** ______________

Scale: ______________ **Offset:** ______________

Calibration Calculations (Completed By: ______________)

Approximate Water Column (ft)	Top of Water Column (ft)	Reference Measuring Point[1] (ft)	Measured Column Above Reference Pt. (ft)	Transducer Reading (ft)	Delta[2] Measured Water Column (ft)	Delta Transducer Water Column (ft)	Percent Error[3] (%)

Notes:
1. Reference point on transducer for measuring the height of water column. Specify if other than tip.
2. Delta = difference between successive measurements.
3. % error = (Measured delta-Transducer delta/measured delta) * 100.

Installation / Removal Data (Completed By: ______ / ______)

Install Date: ______________ **Install Location:** ______________

Depth to Water Below Measuring Point (MP) Before Installation (ft): ______________

Depth to Water Below MP After Installation (ft): ______________ **Transducer Reading (ft):** ______________

Removal Date: ______________

Depth to Water Below MP Before Removal (ft): ______________ **Transducer Reading (ft):** ______________

Comments:

____

____

15.0 – SETTLEABILITY TEST

Purpose and Scope: The purpose of this document is to present general procedures for conducting a settleability test.

Equipment:
Turbidity Meter;
Timer;
1000-mL beaker;
Stirring Rod;
Calibration Standards; and
Personal Protective Equipment.

Documentation:
Daily Field Record (DFR);
Field Instrumentation Calibration Sheet(s);
General Water Sampling Record; and
Settleability Field Form (attached).

This Standard Operating Procedure (SOP) describes the general methodology for conducting settleability testing in the field to determine natural settling characteristics and settling times of suspended solids and/or particulates. Settling tests at the Rico-Argentine Mine Site (site) will help evaluate the treatment effectiveness of the flocculant or coagulant addition to remove particulate iron and other suspended solids from the St. Louis Tunnel discharge.

All settleability tests will be performed by appropriately trained field staff under the guidance of a licensed Professional Geologist or Professional Engineer.

15.1 SETUP AND EQUIPMENT FOR TURBIDITY READINGS

Prior to starting the settleability test, personnel will assemble all necessary equipment for the test and calibration standards. All instruments to be use will be checked and/or calibrated per the manufacturer's instructions and as often as recommended by the manufacturer to ensure they are in proper working condition. Calibration data including the concentration of the calibration standard(s) and the calibration reading for the check standard(s) will be recorded on the calibration form(s) as applicable. Confirm the settleability test with the Project Manager.

The general procedures for the operation, calibration, and maintenance of a field turbidity meter are included in the instruction manual provided with the equipment. In addition, the instruction manual provides information regarding specific calibration requirements and user recommendations. Turbidity meters used can either be part of a multiparameter unit or a single turbidity meter. More details regarding turbidity meters, readings, and calibration are included in SOP 3.0 Field Measurements – Water.

15.2 OPERATION

The following activities must be performed during a settleability test:

- Document general events on a Daily Field Record (SOP 1.0 – Field Documentation and Sample Handling).
- Verify that the appropriate Personal Protective Equipment (PPE) is worn while handling samples (i.e., nitrile gloves).
- Set up a note taking area.
- Calibrate meter to be used for turbidity readings using the procedures described in SOP 3.0 – Field Measurements – Water (e.g. 6920 YSI meter).
- Transfer field sample to fill a 1000-mL beaker and place on a flat surface. The sample should be well mixed, but if there is any discernable separation between water and any solid mass, make note of this level (in mL).
- Allow sample to settle for 45 minutes.
- After 45 minutes, gently stir sample with the stirring rod to release any suspended matter clinging to the sides of the beaker.
- After an additional 15 minutes (at the 1-hour mark), measure the turbidity of the supernatant of the sample using the meter and record results. Also record the time and change in level of the settling solids.
- Allow an additional 1-hour of settling time and record turbidity of the supernatant and level of settled solids again.
- Stop the test at the 2-hour mark after recording results. Settleable solids can be measured in mL/L.
- All field settleability measurements will be recorded on the Settleability Field Form (attached).
- Upon completion of the settleability test, containerize, seal, and label any unused or waste materials. Decontaminate all equipment that has come in contact with the samples (See SOP 4.0 for more details). Containerize, secure, label, and store all waste generated during the course of the settleability study (See SOP 5.0 for more details).

Revision #	Author	Description of Change (Section #)	Date	Reviewer
00	TO/AC AC	Develop SOP. Reviewed and Finalized	9/9/13 9/12/13	TH 9/12/13

ATTACHMENT

Settleability Field Form

SETTLEABILITY FIELD FORM
Rico-Argentine Mine Site
Rico, Colorado

Time / Date	Location ID	Influent Flow Rate	Flocculant Dose Rate (if applicable)	Sample Volume	Is Suspended Material Present on Side of Beaker After 45 Min.	Turbidity of Supernatant After 1 Hour	Volume of Settled Material After 1 Hour	Turbidity of Supernatant After 2 Hour	Volume of Settled Material After 2 Hour	Comments
		gpm	ppm	mL	Yes / No	NTU	mL	NTU	mL	

16.0 – TRACER STUDY

Purpose and Scope: The purpose of this document is to present various types of tracers and general procedures for conducting a tracer test.

Equipment:
Conservative Tracer (varies, fluorescent dye or soluble salt);
Sampling equipment (automatic samplers);
Monitoring devices (fluorometers, conductivity meters, ion specific electrodes, etc.);
Data loggers (optional);
5-gallon plastic buckets (2);
Stream flow meter;
Down-hole pumps;
Miscellaneous tools; and
Safety Equipment;
If creating standard calibration solution for rhodamine:
- 1000-mL volumetric flasks (2);
- 20% rhodamine concentrate;
- Purified water;
- Scale;
- Amber glass bottles.

Documentation:
Daily Field Record (DFR);
Field Instrumentation Calibration Sheet;
Maps/plot plan; and
Camera.

Tracers are used to determine the path of surface water or groundwater flow and to evaluate the hydraulic characteristics of a system. Tracers are dissolved in water at concentrations that do not significantly change the aqueous density. Conservative tracers do not lose mass through reaction or partitioning into differing phases (vapor, solids). Injection of conservative tracers into a system is used to determine the advection and dispersion properties of a surface water or groundwater system.

16.1 PLANNING

All tracer study work will be performed by appropriately trained field staff under the guidance of a licensed Professional Geologist or Professional Engineer.

The following general procedures should be performed prior to the start of a tracer test:

- Identify an appropriate tracer to be used for the tracer test. Refer to Sections 16.1.1 and 16.1.2.

- Model the flow of the tracer from the planned injection well so that the observation wells can be placed at appropriate locations. Refer to Section 16.1.3.

- Provide subcontractors with the applicable scope documents and necessary access information.

- Obtain approval of all appropriate Remediation Management (RM) permits and all permits according to Federal, State, and local regulations.

- Prepare schedules and coordinate with staff, client, and regulatory agencies if appropriate.

- Perform notifications in addition to those described in Section 16.1.4.

- If the tracer has not been pre-mixed by the manufacturer, mix the tracer in a wind-free area, away from sunlight, with all workers in direct contact with the mixing process wearing appropriate personal protective equipment and following appropriate Health and Safety protocols. Record the properties of the tracer (e.g., field meter reading, density, color).

- Prepare, calibrate, and test any meters or data loggers that may be used during the tracer test.

- Determine tracer volume to be used in the study.

- Confirm the tracer test design with the Project Manager.

16.1.1 Types of Tracers

Common tracers used in surface water and groundwater studies include:

- Fluorescent Dyes – rhodamine-WT and fluorescein; and

- Soluble Salts – bromide, potassium, chloride, and lithium.

Fluorescent dyes that are readily detected at low concentrations (parts per billion) and pose little environmental risk can effectively trace groundwater flow paths but may degrade in sunlight or under low pH conditions or may adsorb to porous media. Dye-tracer studies can be used to determine the time-of-travel for groundwater to move to and into surface water, as well as hydraulic properties of aquifers and surface water systems. Depending on the objectives, dye tracers can be detected by visual observation, fluorometric analysis of discrete water samples, and by in-situ continuous-flow fluorometry.

Soluble salts can be detected at low levels but may pose an environmental risk to plants depending on the solute introduced and the concentration. If a known concentration of a solute is injected into the system and measured downgradient over time, the seepage velocity can be calculated. In addition, the amount of dilution at the down-gradient receptors may be used to calculate the discharge. Depending on the objectives, many soluble inorganic salts dissociate in water and may be measured with a conductivity meter (e.g., millisiemens) or an ion-specific electrode (ISE). The concentration of the solute can be calculated by creating a calibration curve that relates the electrical charge to known standard concentrations.

16.1.2 Selecting a Tracer

The most conservative tracer for the site should be selected. This may be determined by consulting tracer manufacturers, by performing a bench scale test, or by consulting case studies.

Contact Tracer Manufacturers

One way to select a tracer is to consult tracer manufacturers to determine if the product can be used for a specific application. Depending on the chemical characteristics of the natural water (e.g., pH, temperature, turbidity, etc.) and the flow characteristics (e.g., surface water flow or flow through porous media), a tracer may be highly reactive and may degrade quickly yielding false or inconclusive results. Any available water quality data should be provided to a manufacturer to determine the most conservative tracer to be used at the site. The manufacturer should provide information on the equipment required to track the tracer.

Perform a Bench-Scale Test

Another way to identify the most conservative tracer for the site is to perform a bench-scale test. Site-specific water samples and porous media that the water may flow through could be mixed with various tracers to determine rates of degradation or sorption and to identify the most conservative tracer for the site.

16.1.3 Modeling Tracer Movement

Tracer migration should be modeled in surface water or groundwater, as appropriate, to estimate the direction of flow and travel time along the flow path. This modeling effort will include estimating the mass of tracer to be added during the tracer study. The mass of tracer to be added will be estimated based on estimated transport calculations, mass balance calculations, and/or results of previous tracer studies. Based on modeling results, an appropriate network of observation points can be placed downgradient of the injection point.

Modeling may include development of a flow net, analytical model, or numerical model and should be based on reasonable assumptions for the hydraulic gradient, flow velocity, and other system characteristics. These models can be used to estimate the direction of flow, advection (i.e., velocity), and dispersion of the tracer to determine the most likely areas where the tracer plume may be identified after injection.

16.1.4 Notifications

Notifications should be made to the local and downstream communities of any tracer tests to be performed within or near a surface water body. Signs should be placed along the stream which the tracer study is being performed. This is especially the case if dye tracer tests are to be performed. Dye tracer tests will discolor the water (fluorescent yellow or red) and may be alarming to the public.

16.2 OPERATION

The following activities must be performed during a tracer study:

- Document general events on a Daily Field Record (SOP 1.0 – Field Documentation and Sample Handling).
- Perform a health and safety tailgate meeting with all personnel performing the tracer test activities. Secure the work zone with traffic cones and barricade tape, as necessary. Verify that the appropriate Personal Protective Equipment (PPE) is worn within the work zone.
- If using rhodamine dye as a tracer, prepare a 100 µg/L calibration standard to calibrate YSI 6920 rhodamine sensors by performing the following:
    - Obtain 20% rhodamine-WT concentrate solution;
    - Weigh and transfer 0.500 g of the rhodamine concentrate to a 1000-mL volumetric flask and fill flask to the top graduation with purified water to create a 100 mg/L solution;
    - Transfer 1.0 mL of the prepared 100 mg/L concentrate to a 1000-mL volumetric flask and fill flask to the top graduation with purified water to create a 100 µg/L calibration standard;
    - Mix the 100 µg/L calibration standard well and store in an amber glass bottle in a refrigerator for preservation;
    - Use standard within five days of preparation.

- If using a conservative tracer, such as sodium bromide, establish a multiple point calibration curve to calibrate the ISE used to measure the concentrations. Refer to SOP 3.0 – Field Measurements – Water for details on operation of ISEs and how to develop a calibration curve.

- Setup a decontamination station. Decontaminate all down-hole tools or surface water sampling tools. Refer to SOP 4.0 – Equipment Decontamination.

- Set up a note taking area.

- Calibrate and test the down-gradient/downstream monitoring devices – automatic samplers, in-situ continuous-flow fluorometry meters, or fluorometers.

- Set up the down-gradient/downstream monitoring devices – automatic samplers, in-situ continuous-flow fluorometry meters, or fluorometers. If data loggers are to be used, program the start time, frequency of sample measurement, and end time. The start time for all monitoring devices should be chronologically set to begin simultaneously. Document the location of each monitoring point on a map.

- Measure and record the influent flow rate (for tracer studies conducted in surface waters only).

- Inject the tracer and record the time. The tracer should be introduced as a "plug" or a single, rapid injection. If injected into surface water, the tracer may be directly poured from the container or a bucket into a well-mixed section of the stream. If injected into a borehole, the tracer may be pressure injected or allowed to infiltrate with gravity.

- Use an appropriate meter to measure the tracer at each observation point; observation points may include the injection location and downgradient/downstream monitoring points. Record the time and change in concentration at each observation point during the test. The method of tracking the tracer will depend on the objectives of the tracer test and the type of tracer used. Dye tracers may be visually observed with the first arrival times recorded, fluorometric analysis of discrete water samples, or by in-situ continuous-flow fluorometry. Solute tracers may be measured with a conductivity meter or ISEs as an electrical charge and later converted to concentration values.

- Stop the test when the plume of tracer has traveled past all monitoring points.

- Upon completion of the tracer test, containerize, seal, and label any unused or waste materials. Decontaminate all equipment that has come in contact with the tracer chemicals. Containerize, secure, label, and store all waste generated during the course of the tracer study.

16.3 REVISION LOG

Revision #	Author	Description of Change (Section #)	Date	Reviewer
00	ARC	Prepare SOP. Technical Review Reviewed and Finalized	 MM AC	 9/11/13 9/24/13